THE PHYSIOLOGY OF THE NEW-BORN INFANT

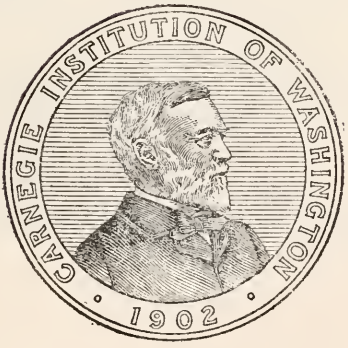
CHARACTER AND AMOUNT OF THE KATABOLISM

BY

FRANCIS G. BENEDICT

AND

FRITZ B. TALBOT



WASHINGTON, D. C.
PUBLISHED BY THE CARNEGIE INSTITUTION OF WASHINGTON
1915

H15-(1)
4

CARNEGIE INSTITUTION OF WASHINGTON
PUBLICATION NO. 233

9405

PRESS OF GIBSON BROTHERS, INC.
WASHINGTON, D. C.

PREFACE.

The investigation on new-born infants reported herewith is a natural outcome of the attempt of this laboratory during the last four years to secure adequate information regarding the normal metabolism of infants preparatory to a contemplated study of pathological conditions, for until normal data are available an intelligent interpretation of the data from pathological cases is impossible.

The observations have been made by Miss Alice Johnson, whose skillful technique and experience in studies of infant metabolism have contributed greatly to the research. To the trustees and especially to the superintendent of the Massachusetts General Hospital we wish to express our thanks for the facilities offered to us in the prosecution of this study. Through the kindness of the trustees and staff of the Boston Lying-In Hospital, a large number of new-born infants were made available for this research. The majority of the infants used in these observations came from this institution. Much credit is also due the nurses of the hospital for their active interest and cooperation, which materially assisted in the successful outcome of the research.

NUTRITION LABORATORY OF THE
CARNEGIE INSTITUTION OF WASHINGTON,
Boston, Massachusetts, July 31, 1915.

CONTENTS.

	PAGE
Introduction	7
Embryonic conditions	7
Post-natal conditions	8
Loss in body-weight	9
Earlier researches with new-born infants	12
Observations by Hasselbalch	15
Purpose and plan of the research	38
Apparatus and tests for accuracy	38
Method of computation	39
Care of the new-born infant	41
Statistics of the observations	43
Discussion of results	80
Character of the katabolism	80
Respiratory quotient during the first 24 hours of life	80
Respiratory quotient during the first week of life	89
Influence of body-weight upon the respiratory quotient	91
General conclusions as to character of katabolism of new-born infants	92
Basal katabolism	94
Total minimum heat-production per 24 hours	97
Minimum heat-output per kilogram of body-weight per 24 hours	98
Minimum heat-output per square meter per 24 hours	99
Influence of age upon the katabolism	102
Influence of age upon the heat-production in the first day	103
Influence of age upon the heat-production from the second to the seventh day	105
Influence of length upon the basal katabolism	106
Influence of activity upon the basal katabolism	111
Pulse-rate	113
Physiological needs *vs.* supply	117
The conservation of energy	118
Body temperature	118
Methods for reducing the energy loss	121
The energy intake	122
Probable 24-hour energy requirement of a new-born infant for maintenance	126

ILLUSTRATIONS.

FIG.	1. Respiratory quotients of infants found at times during the first 24 hours	88
	2. Respiratory quotient of infants in first 24 hours referred to total body-weight	91
	3. Respiratory quotient of infants in first 24 hours referred to body-weight per unit of length of infant	91
	4. Minimum heat-production of new-born infants per 24 hours referred to the body-weight	97
	5. Minimum heat-production of new-born infants per kilogram per 24 hours referred to the body-weight	99
	6. Minimum heat-production of new-born infants per square meter of body-surface per 24 hours referred to the body-weight	101
	7. Minimum heat-production of new-born infants per 24 hours referred to age	103
	8. Minimum heat-production of new-born infants per kilogram of body-weight per 24 hours referred to age	104
	9. Minimum heat-production of new-born infants per square meter of body-surface per 24 hours referred to age	105
	10. Minimum heat-production of new-born infants per square meter per 24 hours computed per centimeter of length for infants between $1\frac{1}{2}$ and 6 days old	107

THE PHYSIOLOGY OF THE NEW-BORN INFANT

CHARACTER AND AMOUNT OF THE KATABOLISM

BY

FRANCIS G. BENEDICT AND FRITZ B. TALBOT

INTRODUCTION.

In our observations on the gaseous metabolism of infants, which were begun over three years ago, we have been impressed by the fact that while observations on three or four infants would admit of conjectures which might subsequently be in part verified by multiplication of data, yet of themselves they could necessarily have very little conclusive value. Accordingly, as it is the purpose of this laboratory to secure sufficient data to eliminate, so far as possible, the personal equation, we frankly stated in our earlier publication[1] that we were still occupied in "overcoming the paucity of results obtained with normal infants," and similar statements were made with regard to the new-born infants. Our observations of new-born infants were begun in the latter part of 1913 and were freely discussed with the investigators working in the same field. There seems to have been a disposition on the part of some investigators to relieve us of the responsibility of interpreting certain of our results; consequently, we present here our complete data in regard to the character and amount of the metabolism of 105 new-born infants, 74 of which were studied within 24 hours of birth.

EMBRYONIC CONDITIONS.

Although the interest of the embryologist in the prenatal development of the infant begins at the moment of conception, it is not until the fetus has reached a considerably advanced stage of development that an intelligent interest can be taken in its metabolism. Histological studies show that the composition of the embryo is not materially different from that of the adult organism. Food is carried to the placenta by the blood of the mother and we have no reason to believe that there is in the prenatal life any marked difference between the mother and the fetus in the character of the katabolism. On the other hand, histological studies[2] do show that there is in the embryo a relatively large proportion of glycogen. While this is shown microscopically, it has not as yet received verification by chemical analysis. At the present time, therefore, the common belief in a large supply of glycogen in the embryo is based solely upon histological studies, made almost entirely on animals, and it is well known that the results of histological

[1]Benedict and Talbot, Am. Journ. Diseases of Children, 1914, **8**, p. 43.

[2]Gierke, Lubarsch-Ostertag's Ergeb. Jahrb., 1907, **11** (2), p. 880. Also, Lubarsch, Virchow's Archiv, 1906, **183**, p. 188. Most of the work has been done on animals, with the single exception of that by Lubarsch. Lubarsch examined a 9-weeks human embryo and a 4 to 5 months human fetus, and concluded that the amount of glycogen varied with the age and the species. The muscles contain a considerable amount of glycogen even in the embryo, while glycogen is only deposited in the liver in later embryonic life. Mendel and Leavenworth (Am. Journ. Physiol., 1907–8, **20**, p. 117) add to Gierke's extended review of the literature on the subject.

studies and chemical analyses do not necessarily agree.[1] It is generally considered, however, that the fetus has a larger supply of glycogen in proportion to its weight than has the mother. If, as we believe, the character of the combustion is determined in large measure by the character of the available food-supply, it is not inconceivable that there may be a larger combustion of glycogen and a specific fetal katabolism. On the other hand, the oxygen and food are obtained from the blood of the mother, and while the fetus may be glycogen-rich, the liver of the mother is likewise glycogen-rich, and hence it may be unreasonable to expect a specific gaseous metabolism of the embryo in the pre-natal state.

It is hardly probable that with our present technique we can rationally interpret the character of the katabolism of the fetus by measuring the gaseous metabolism of the mother and the child before the birth of the child, and the mother alone after delivery, for as the metabolism of the mother is very much greater than that of the child, a differential method is liable to very great error.

POST-NATAL CONDITIONS.

As soon as the child is born all of the conditions are changed. Prior to birth the fetus is living on a rich food-supply which is brought by the maternal blood. Immediately after birth this supply is cut off and no food is thus derived from the mother. The infant then begins to starve, that is, to draw upon its reserve body-material until the mother's breasts secrete enough food to supply its demands. We may properly ask, what is this reserve and how does it influence the character as well as the totality of the katabolism? The amount of the material burned we know is determined in large part by the muscular activity of the infant, but since now the infant must live (for the first hours, at least) solely upon its own body-reserve, the character of the material available for combustion and the character of the material actually burned present a new interest.

No mammal mother is so completely incapacitated for carrying out the duties necessary to protect and nourish her young during the first few days after parturition as is civilized woman. On the first day after birth, the mother is usually absolutely dependent upon the ministrations of others. The infant must likewise share this dependency upon others. Even the natural food-supply of the parturient mother is extraordinarily small, for the total fuel value of the colostrum is insufficient during the first few days, even under the most favorable circumstances.[2]

We may question, then, is the new-born child automatically adjusted to this state of affairs? Is the body-supply sufficiently liberal to provide for the draft upon it, and have we really, therefore, a self-contained little engine? What are the infant's needs for the first few days?

---

[1] Rusk, Proc. Soc. Exp. Biol. and Med., 1912, **10**, p. 21.
[2] See page 122.

First, the infant must keep up its vitality. In the prenatal condition it has been in a moist, warm medium, with no loss of heat by radiation or by the vaporization of water. By birth it is suddenly thrust into a much less moist and often cold environment. It is currently believed that this change is in some way actually beneficial, since it acts as a stimulus to the vital activities of the infant. But immediately after birth the child is required to make up for the heat lost by radiation, which is considerable, and for that used in the vaporization of water from the body-surface. In the few days subsequent to the birth the infant's heat-regulating mechanism is extremely imperfect. It is first called into play as soon as the child is delivered. A bath is usually given shortly after the delivery, which, with its attendant exposure of the body, unquestionably increases the heat loss. There is, however, almost invariably an increased heat-production as the result of muscular activity and frequently loud, vigorous crying.

We may classify the new-born infant's needs under two gross categories: first, the need for maintenance, and second, the need for growth. Since, in our discussion, we are interested for the most part in the consideration of the metabolism during the first week of life, we may properly at this time omit consideration of the question of growth and confine ourselves exclusively to the maintenance requirements. The question, then, is: Can the infant in the first week of life obtain sufficient nourishment from its mother, even a normal mother, to maintain its vital activities without loss of body-substance? An examination of the records of body-weight will be of interest in this connection, for a loss in weight, if any, may be considered a crude index of the infant's needs.

LOSS IN BODY-WEIGHT.

Shortly after birth there is normally a very considerable loss in body-weight. The average duration of this loss in weight is 2 to 3 days, the length of time depending upon when the mother's milk-supply is sufficiently established to provide the infant with enough nourishment for its needs. If an infant continues to lose weight after the fourth day the cause must be pathological. As may naturally be expected, the time and amount of the secretion of the breast-milk are the principal factors in determining the amount of weight lost. The loss of weight varies according to different investigators, but usually lies between 150 and 300 grams,[1] with an extreme high figure of 700 grams.[2] A loss of even 400 to 500 grams has been observed with infants which have shown no pathological disturbance at the time or later. In general, the smaller the baby is at birth, the greater will be the relative proportion of the weight lost, the usual proportion being between 6 and 9 per

[1] von Reuss, Die Krankheiten des Neugeborenen, Berlin, 1914, p. 2.

[2] Czerny and Keller, Des Kindes Ernährung, Ernährungsstörungen und Ernährungstherapie, Leipsic and Vienna, 1906, **I**, p. 554.

cent of the birth-weight. Trepper[1] has concluded that the percentage loss was greatest with weak, undeveloped infants, least with those of average weight, increasing again, not only absolutely but relatively, with large infants because of the greater trauma during birth.

But the loss in body-weight of the new-born infant may not be taken as an index of its physiological needs for nourishment, as an analysis of the character of this loss in weight shows us that there are two distinct causes: (1) mechanical and (2) physiological.

Within a few hours after birth the infant passes urine and meconium and at times regurgitates allantoic fluid from the stomach. No one of these can be said to represent a loss due to the physiological disintegration of body-substance, but they should all be classified under the head of mechanical loss.

Subsequently there is a loss of body-material or body-reserve which should be considered as definitely disintegrative. When a previously nourished organism is subjected to complete inanition or withdrawal of food, there is in all cases a marked loss in weight during the first period of the fast, and as the fast progresses the loss becomes considerably less per unit of time. This is strikingly noted in experiments with fasting animals, and, indeed, in those with man, and receives a logical explanation in view of modern studies which show that there is an excessive water-loss during the earlier stages of inanition. Exactly the same conditions may be said to exist in the case of new-born infants. Before birth the infant was in a moist environment and the body was therefore surcharged with water. A not inconsiderable amount of this may be lost very shortly after birth through vaporization from the skin and lungs, particularly when active crying takes place. This water should be considered as preformed water existing in the body.

But the most important physiological loss is that due to the actual oxidation of body-substance as a result of metabolism. With the first moment after delivery and as soon as the lungs have become filled with air, the infant begins to oxidize body-substance, this material being chiefly fat, with some protein and some carbohydrate. This material is carried off in the form of carbon dioxide and of oxidized organic hydrogen, and thus contributes its quota to the physiological loss.

Since the loss of meconium, allantoic fluid, and urine, and even of preformed water, is not accompanied by energy transformations and the liberation of heat, we may estimate the true physiological loss by determining the energy loss either directly or, what is more practicable, by the indirect method of measuring the carbon-dioxide output and the oxygen consumption.

Although it is a popular conception that the new-born infant has a very much larger metabolism than has the adult, evidence that we

[1]Trepper, Ueber die Gewichtsabnahme der Neugeborenen, Inaug. Diss., Giessen, 1913.

have already published[1] in discussing an entirely different subject, namely, the metabolism per square meter of body-surface, shows that new-born infants have a relatively low heat-production per square meter of body-surface. The calorific needs for these infants may therefore be legitimately considered as extraordinarily low. If we compute the calories required for a new-born infant on the basis of the experiments previously published by us, we find that the daily heat-output of a quiet, resting new-born infant of approximately 3.76 kilograms corresponds to the oxidation of about 17 grams of fat. Since the total loss in weight during the first few days is 200 to 300 grams, it can be seen that only a small proportion of this loss can consist of organized body-tissue, such as fat. Even if the entire energy output were derived from the combustion of carbohydrate, the amount katabolized, *i. e.*, approximately 40 grams, or about twice the amount corresponding to the katabolism of fat, would still be too small to account for this loss in body-weight. The relatively small amounts of protein katabolized may properly be disregarded in discussing this phase of the total metabolism. Hence the only other alternative we deal with here is the loss of a large amount of water.

In the foregoing considerations, however, the assumption is made that the infant is undergoing complete starvation. As a matter of fact, a certain, although admittedly deficient, amount of nourishment is obtained from the small amount of colostrum available. This would, in part at least, tend to retard any physiological loss in weight and a consideration of this fact only accentuates the contention that the loss in weight, *per se*, can not be an accurate index of the food requirement of the new-born infant.

---

[1]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 157; also, Am. Journ. Diseases of Children, 1914, 8, p. 1.

EARLIER RESEARCHES WITH NEW-BORN INFANTS.

Considering the marked physiological loss in weight during the first week of life, the rapidly changing character of the nourishment, and the supposed imperfect heat regulation of the new-born infant, together with the fact that all human beings must pass through the experiences of this period, it is surprising that so little evidence regarding both the character and the amount of human metabolism during the first week of life is available. There are almost no reliable observations on the character of the katabolism and the majority of observations on the amount of metabolism are, in the light of present-day technique, seriously vitiated by the fact that, at the time the researches were made, the importance of complete muscular repose on the part of the infants was but imperfectly realized.

OBSERVATIONS BY MENSI.

Although Forster,[1] in 1877 studied the carbon-dioxide output of an infant 14 and 60 days after birth, and 10 years later Langlois[2] studied the heat-production of an infant 15 days old, it was not until the research of Mensi[3] in 1894 that we find any observations on the gaseous metabolism or heat-production of infants during the first week of life.

As a matter of fact, Mensi's infants were all somewhat under the normal weight of a new-born infant, and while the oxygen consumed per kilogram per minute, as reported by Mensi, appears to be reasonably uniform, the extraordinarily low respiratory quotients noted by him still leave the experimental procedure somewhat in doubt. The apparatus used by Mensi has, so far as we know, never been described. After a number of efforts we have finally been able, through the kindness of Professor G. Fano of Florence and Professor Herlitzka of Turin,

[1]Forster, Amtlicher Bericht der 50. Versammlung deutsch. Naturforscher u. Aerzte in München, Munich, 1877, p. 355. Supplementary data regarding these two observations were given in a personal communication to Professor Magnus-Levy and published by him in the Archiv f. Anat. u. Physiol., 1889, Suppbnd., p. 314. According to Professor Forster, the data were obtained on a girl, "bei ziemlicher Ruhe." Although the infant was older than those included in our own study, we consider the material of sufficient importance to give the following tabular data, which were published by Magnus-Levy regarding Forster's observations:

Age.	Weight.	Carbon dioxide eliminated per hour.	Carbon dioxide eliminated per kilogram per hour.	Carbon dioxide eliminated per minute.	Carbon dioxide eliminated per kilogram per minute.
days.	*kilos.*	*gm.*	*gm.*	*c.c.*	*c.c.*
14	2.70	2.52	0.93	21.40	7.89
60	3.78	3.68	0.97	31.07	8.22

[2]Langlois, Journ. de l'Anat. et de Physiol., 1887, **23**, p. 400. Langlois' observation on an infant 15 days old was only incidental and, in view of the known errors of the calorimeter employed, the values can have only an historic interest.

[3]Mensi, Giorn. d. R. Accad. di Med. di Torino, 1894, **57**, p. 301. An abstract of Mensi's observations was given in our earlier publication. See Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 14.

to secure information from Mensi regarding the apparatus and the technique used in the observations. The infant was placed under a bell in which air was circulated. The carbon-dioxide output was determined by barium hydroxide, while the oxygen consumption was found by measuring the amount used from a flask of known capacity in replacing the oxygen consumed by the infant. The principle of the apparatus appears to be essentially that of Regnault and Reiset.

OBSERVATIONS BY SCHERER.

Perhaps no research on the gaseous metabolism of infants is more frequently cited as being the earliest and of the greatest significance than is that of Scherer[1] in the laboratory of Professor Mareš in Prague. As pointed out in our earlier consideration of these experiments,[2] the extraordinarily low respiratory quotients found by the investigator lead one to doubt the accuracy of the determination of the gaseous metabolism. In the latter part of his article, Scherer discusses the protocols of one experiment, which he gives in detail, and points out the fact that Mareš considered that the increase in the nitrogen of the air inside the chamber should be taken as an indication of the accuracy of the experiment, since the smaller the nitrogen accumulation, the more accurate is the experiment.

Unusual attention was paid in the Prague laboratory to the possibilities of leaks into or out of the respiration system, and the earlier work in Pflüger's laboratory was keenly criticized by Mareš[3] in the original description of his apparatus for studying the metabolism of animals during hibernation. In this Bohemian monograph Mareš devotes several pages to a discussion of the possibilities of error due to leaks, to the accumulation of nitrogen, and to the rôle the nitrogen may play in the total metabolism, and gives a number of arguments for and against the belief that free nitrogen rises from protein disintegration. It is surprising, therefore, to find that Scherer assumed the percentage composition of the compressed oxygen used by him to be that determined by an old analysis. This point can best be considered in connection with the keen criticism of Scherer's experiments by Hasselbalch in the excellent paper which will be presented somewhat later in this report.

Scherer made 55 experiments in the spring and summer and 30 experiments in the winter, each experiment being about 2 hours long. A considerable number of these experiments were with infants 7 days old or under, namely, 24 experiments in the summer and 7 experiments in the winter. It is most unfortunate that at this period in the development of the respiration apparatus in the Prague laboratory control

[1]Scherer, Jahrb. f. Kinderheilk., 1896, N. F., **43**, p. 471.
[2]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 14.
[3]Mareš, Arch. bohêmes de méd., 1889, **2**, p. 458.

tests were not made with burning alcohol. Although such tests are cited in the reports of later investigations in this laboratory, Scherer gives no description of control tests made by him.

OBSERVATIONS BY BABÁK.

The next research on this subject published from the Prague laboratory was that of Babák,[1] which appeared in Bohemian in 1901 and in a somewhat abridged form in German in 1902. Babák's investigations dealt primarily with the study of the heat regulation, the Bohemian paper being prefaced by an extended consideration of theoretical points involved in the discussion of the chemical and physical heat regulation; evidently this was the whole trend of his discussion and his experimental research, his interest in the gaseous metabolism of new-born infants being only secondary.

Babák used a respiration apparatus of the Regnault-Reiset type, which was, indeed, the apparatus originally employed by Scherer but later somewhat modified by the attachment of calorimetric devices on the d'Arsonval principle. The control tests, which were made by the burning of alcohol, are reported to give an accuracy of 2 per cent within theory for the oxygen consumption and 6 per cent within theory for the carbon-dioxide production. This large error in the carbon dioxide is, we believe, unique with the Regnault-Reiset type of respiration apparatus, for with all of the apparatus that we have thus far investigated we have found that the determinations of the carbon dioxide are usually extraordinarily exact, practically all of the errors falling upon the oxygen. Since no protocols are given by Babák, either in the German paper or in the Bohemian paper, further intelligent discussion of the technique is impossible. In all 63 experiments were made with 7 infants, ranging in age from 1 to 8 days. No records were published for these infants of the degree of activity or of the pulse-rate. We can not, therefore, compare the total metabolism as measured by this type of apparatus with the results of modern researches.

As the alcohol control tests of Babák's calorimeter never showed an extraordinarily high degree of accuracy, and as Babák's problem was simply to determine the temperature regulation of the new-born infant, it is not surprising that in the German article he gives but a few words to the discussion of the respiratory quotient, only making the statement that, like Scherer, he found the respiratory quotient

[1]Babák, Rozp. Č. Akad. Císaře Františka Josefa, Třída II, Ročník X, Číslo I, 1901, and Archiv f. d. ges. Physiol., 1902, **89**, p. 154. The reference to the German publication of Babák's researches was inadvertently omitted from our two previous communications. (See Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, and Am. Journ. Diseases of Children, 1914, **8**, p. 1.) At the time the literature was being assembled we were awaiting a complete translation of the original Bohemian article, and as this could not be finished prior to publication it was not inserted. The absence of the German reference was clearly an omission. At this point we would like to state that the Bohemian article has been translated by Miss B. Haderbolets, the Bohemian translator of the Nutrition Laboratory, and a copy is on file in the laboratory.

to be somewhat lower in winter than in summer. In the Bohemian article we find a somewhat more extended discussion of his results, inasmuch as Babák points out that the respiratory quotient does not show regularity, this being largely due to variations in the carbon-dioxide determinations. The majority of the low values for the respiratory quotients were found during the low temperature of winter, and Babák concludes that since similar observations were obtained with rabbits he can corroborate the discovery of Scherer that in winter assimilation is greater than disassimilation, or that anabolism is greater than katabolism.

OBSERVATIONS BY HASSELBALCH.

In 1904 Hasselbalch,[1] publishing in a remote place, presented a most interesting paper on respiration experiments with new-born infants. At the time of going to press with our earlier publication, this Danish contribution was in process of translation, and hence it was not then cited by us. Upon the completion of the translation, for which it is a pleasure to thank Miss Alice Johnson, of the Nutrition Laboratory staff, and Dr. M. N. Smith-Petersen, of the Peter Bent Brigham Hospital, we are so impressed with the accuracy of the technique and the clear-cut conception of Hasselbalch's conclusions that we feel it is incumbent upon us to make this material available to readers in other than Danish, and hence it is here reprinted. We wish to express our thanks to Professor Hasselbalch for his kindness in looking over the manuscript and making some slight alterations in the phraseology of the translation.

[1]Hasselbalch, Respirationsforsøg paa nyfødte Børn, Bibliotek for Laeger, Copenhagen, 1904, **8**, p. 219.

Respiration Experiments With New-Born Infants.

By K. A. Hasselbalch.

The desirability of carrying out total metabolism experiments on healthy and sick infants with a view to obtaining information regarding the adequate nourishment of the infant is very evident. So long as it is not an established fact how the healthy and normally-nourished infant utilizes the fat and carbohydrate of milk, so long every therapeutic treatment of the fatal conditions in pedatrophia is absolutely guesswork, and so long the composition of the countless strength-giving foods for artificially nourishing infants is based on the roughest empiricism by observing the changes, if any, in the curve of the body-weight.

While the present paper does not report experiments on total metabolism, a study of the respiratory exchange of the new-born infant is also of considerable interest. In the first place, the amount of the respiratory exchange, because of its considerable excess over the nitrogen exchange, may be used as an expression of the amount of the total metabolism, and in the second place the respiratory quotient throws light on the substances oxidized in a given period of time.

It is generally believed that a young individual has a greater metabolism per kilogram of body-weight than the adult, because of its greater surface in relation to its body-weight and because it is growing. I shall not enter into a discussion of the rather contestable "law of surface area" which is the subject of so much dispute. My experiments can not be used to support such a discussion successfully, for it is rather difficult with young children to represent fairly the same external and internal experimental conditions as are represented by other investigators in their respiration experiments with adults. In one respect only can my experiments give enlightenment, that is, as to the influence of exercise on the amount of the metabolism. From experiments during which the infant slept quietly I have obtained material whereby I could form my own point of view in regard to the dogma concerning the relatively large metabolism of the infant. If it is possible from the experiments to come to an approximate conclusion concerning the amount of the metabolism of the new-born sleeping infant, this conclusion has a special interest as bearing directly on the fetal life. In the embryonic condition it is well known that the metabolism per unit of body-weight is as great as with the grown individual of the same species.

The respiratory quotient, obtained as soon as possible after birth, gives information as to the approximate composition of the new-born infant's fuel material and permits an assumption as to its composition in the embryonic state. The breast-fed infant—and the infant that directly after birth has been given the spoonful of cane-sugar solution traditional in Denmark[1]—give the experimenter some idea of the time

[1]The following information regarding this practice is kindly supplied by Hasselbalch in a personal communication: "The midwife gives the child a teaspoonful or two of a weak cane-sugar solution (strength of solution quite accidental) after the child is washed and before it is put to bed. We suppose the reason to be that the child should not be starving until the mother has milk enough for it. Generally the administration of cane-sugar is not repeated, as the rôle of the midwife is now over and the nurse's work begins."

required for the absorption and oxidation of the three nutrients in the food—the protein, fat, and carbohydrate.

The only complete respiration experiments on new-born infants known to me were undertaken first at Prague under the direction of Mareš by Scherer[1] and Babák.[2] The experiments of Babák on the respiratory exchange are only a link in the investigation of the new-born infant's heat regulation. The surprising result of both these investigators' experiments is this, that not only after birth, but even with infants several weeks old, an unusually low respiratory quotient was found. Scherer reports 55 summer experiments with respiratory quotients ranging from 0.567 to 0.898; in 27 instances the quotients are under 0.70, a quotient which, for the grown individual, is the lowest imaginable, at least for rather long periods of time. His 30 winter experiments show but one quotient over 0.70; the lowest is 0.493, the highest 0.717. Babák's experiments generally show a higher quotient, but 0.51 is not uncommon with him.

To explain these low quotients, which are ordinarily found only with hibernating animals, Scherer has to resort to the explanation generally assumed for these animals, *i. e.*, an incomplete burning of food material, whereby the oxygen taken in does not leave the organism in its entirety as carbon dioxide, but to some extent is stored up in the form of unstable compounds. Scherer, in attempting to explain the significance of this saving of oxygen in infancy, refers to the "excess of anabolism over katabolism"; but this conclusion does not hold true. In the fetal life, then, one must also expect low quotients, lower than with the free oxidation of the embryo's food material. But the chicken embryo burns fat and has a fat quotient, 0.71; the guinea-pig embryo has a carbohydrate quotient[3] of 1.00. The snake embryo has a mixed quotient, about 0.85, while with the silk-worm embryo[4] the respiration takes place with a diminution of both fat and carbohydrate, which naturally would result in a quotient between 0.7 and 1.0.

The hypothesis presented by Farkas,[5] partly in reference to the fat quotient with the bird embryo and partly in reference to Scherer's and Babák's low quotients with new-born infants, "während der embryonalen Entwicklung und in den ersten Stunden des Lebens überwiegend Fett verbrannt wird," may be disputed. The different animal classes can not be expected to nourish their embryos with the same material; that they do not do this has already been mentioned, and Farkas himself brings forward a new example to demonstrate this point.

In view of the doubtful respiratory quotients found by Scherer and Babák, we must reject in advance Scherer's second conclusion concerning the amount of the respiratory exchange. Eighty-five experiments are mentioned, not with the same child, but with different children at different times. From this material, without taking into consideration the child's condition during the experiment, such as movements, crying,

[1]Scherer, Jahrb. f. Kinderheilk., 1896, N. F., **43**, p. 471.
[2]Babák, Archiv f. d. ges. Physiol., 1902, **89**, p. 154.
[3]Bohr, Vidensk. Selsk. Forh., 1900.
[4]Farkas, Archiv f. d. ges. Physiol., 1903, **98**, p. 490.
[5]Farkas, *loc. cit.*, p. 517.

digestion, etc., Scherer and Babák draw the following quite unjustifiable conclusion: "Die Kohlensäureproduction und der Sauerstoffverbrauch sinken beim Neugeborenen etwas in den ersten Stunden nach der Geburt bis ung. zur neunten Stunde," etc. If a new-born infant kicks and cries soon after birth, is afterwards quiet and sleeps almost to the ninth hour, then wakes and is laid at the breast, the results obtained would nearly agree with the quotation given above, but otherwise not. Speck,[1] a well-trained subject for physiological experiments, tripled his respiratory exchange by doing considerable work with one arm. So great is the influence of muscular contractions upon metabolism that the arrangement of a schedule like the one indicated above is rather a waste of time.

Scherer and Babák have worked with the same respiration apparatus. That their results agree quite well, therefore, is but natural. If their results are incorrect, as I must assume after carrying out my own experiments, this can not be due to the inaccuracy of their methods (although the limit of error of 6 per cent for carbon dioxide is quite large, the respiratory quotient can in a given instance vary from 0.65 to 0.60), but must have its reason in a systematic error. I refer to Scherer's description of his experiments, from which it is clear that in the closed respiration apparatus after the experiment there may be found an increase of 541 c.c. beyond the calculated nitrogen quantity; the oxygen consumed is replaced from an oxygen bomb; the oxygen introduced into the chamber is not analyzed for its purity, but is assumed from "Hoppe-Seyler's analysis" of the same manufacture to contain 4 per cent nitrogen; if, in reality, it contains over four times as much (which is perhaps unreasonable but always possible), this would explain the finding of 541 c.c. of nitrogen in excess. If on this basis a correction is made in the above case, the quotient rises from 0.63 to 0.73.

I do not dare insist that this explanation is very probable; from the account of the experiment, however, I find no other. At any rate, I may say that a method with such large sources of error is too crude to be compared with mine, which has given especially accurate results in the hands of numerous investigators. My method of experimentation is given herewith:

The atmospheric air from outside is drawn through a water gas-meter, and from there through a large spiral lead pipe, where it is warmed to the experimental temperature. The infant lies naked in a 15-liter respiration chamber, which is placed within a couveuse. The air is sent into one end of the respiration chamber at the top, passes out below at the opposite end, and through a flask where the moisture of the expired air and the perspiration is condensed. After this the air-current is passed into a simple sampling apparatus, consisting of a mercury receptacle closed with three-way taps, from which the mercury can run out in a thin stream during an experiment. By this means almost continuous samples of the air-current, each with a volume of 70 c.c., may be obtained; 50 c.c. of the sample are used immediately for an analysis in a Pettersson apparatus (with potassium pyrogallate). The air is sucked over the child by means of a water-suction pump; the speed, which is sufficiently even for our purpose, with variations never over 3 per cent, is regulated according to the percentage of carbon dioxide one desires in the respiration chamber. The samples of air are not taken until the infant has remained in the air-current so long that we can assume a uniform composition, *i. e.*, when three times its own volume of air has been passed out of the respira-

[1]Speck, Physiologie des menschlichen Athmens, Leipsic, 1892, p. 82.

tion chamber, after at least 12 to 15 minutes or longer, according to circumstances. The atmospheric air is analyzed either on the day of the experiment, or, in case of evening and night experiments, the following morning. (The occasionally rather insignificant variations in the composition of the atmosphere during the experiments is without influence on the results, so that now and then an atmospheric analysis is omitted. I have then made my calculations, using the preceding day's analysis.) From the percentage composition of the air before and after it passes into the chamber the respiratory quotient is estimated (with a small reduction based on the supposition that the nitrogen does not take part in the respiratory exchange) and from the quantity of air which has circulated in the respiration chamber during the experiment and which has been determined by the gas-meter, the absolute amount of the metabolism is calculated, with a reduction for pressure and temperature.

The temperature during the experiment as recorded by a thermometer inside the respiration chamber, fastened firmly to the under side of the glass top or ceiling of the chamber, varies during the experiment between 31° and 35° C. The intention was to supply perfect physiological conditions for the infants. Since, as a rule, they had been submitted to the customary bath and had a particularly low temperature previous to the experiment, the body temperature rose sometimes several degrees, but never above normal. This rise in temperature occurred almost entirely during the 15 minutes that preceded the experiment proper, so that the temperature of the child (see in tables the last figures under "Body temperature") can be considered as nearly constant during the experiment.

The degree of humidity in the air is also physiological, since the inspired air, saturated with moisture at the temperature of the gas-meter (15° to 20° C.), is afterwards warmed to about 32° C. before it is inspired. The duration of an experiment is from 22 to 24 minutes for each single determination. As regards the accuracy of the method, even if the greatest possible errors in analyses are made (according to numerous double determinations of the atmospheric air), this could alter the respiratory quotient only 1 or 2 in the third decimal place. The weights of the children can not be counted on to give a greater accuracy than ±25 grams; partly for this reason and partly because the limit of error for the reading of the gas-meter is ±0.5 per cent, the error in the determination of the amount of the metabolism per kilogram of body-weight and per hour may be counted as ±2 per cent of the reported value.

When we consider that the respiratory quotient of the guinea-pig embryo is about 1.0, even when that of the mother animal is considerably lower, it is natural to expect that the new-born infant, which is born with a greater or less store of glycogen in its liver, would live exclusively at the expense of this supply in the first hours of its life and accordingly give a carbohydrate quotient. This should be all the more true, the shorter the interval between the birth of the child and the beginning of the experiment.

From table 1, in which 6 respiration experiments with new-born infants weighing over 3,000 grams are arranged chronologically, it is evident that the relationship is not quite so simple. The youngest infant, which was 45 minutes old at the beginning of the experiment, and one of the two oldest, which was 2 hours old, show quotients of approximately 1.0, but in experiments 3, 8, and 7 a mixed exchange takes place, in which carbohydrates are chiefly concerned; in experiment 12 we find a pure albumin quotient, which can also originate from the burning of much fat and few carbohydrates.

If we now examine table 1 more closely, we see quickly that the subject of experiment 2, with a pure carbohydrate quotient, is recorded as "fat and strong"; its weight is also striking in comparison with its length (3,650 grams to 51 cm.). Although in experiment 9 no general impressions of the infant's condition are recorded, it is obvious from the weight and height that this was also a particularly well-nourished

child. At the other extreme is the infant in experiment 12, who, with a very low quotient, is heavy, but with a disproportionate length and consequently thin. If, then, having the condition of nourishment in mind, we examine the remaining experiments, it appears for the present as if *the better nourished the infant is the nearer to 1 is the respiratory quotient of the new-born fasting infant in the first hours after birth.* We will discuss later the possible influence of the other experimental conditions on the quotient. If these values are correct the period of time after birth affects the results in such a manner that with the same infant in two consecutive determinations the quotient falls from experiment to experiment.

TABLE 1.[1]

Experiment No.	Sex.	Body-weight.	Height.	Age.	Temperature of air in apparatus.	Body-temperature (rectal).	Carbon-dioxide in air of chamber.	Carbon-dioxide elimination per kilogram per hour at 0° C. and 760 mm.	Respiratory quotient.
		gm.	*cm.*	*hr. m.*	*°C.*	*°C.*	*p. ct.*	*c.c.*	
[2]9	F.	3,750	51	.. 45	34.0–35.0	.....	0.873	333	0.970
[3]3	M.	3,100	51	1 30	34.3–35.0	32.8–35.2	.669	481	.868
[4]8	F.	3,950	54	1 30	33.5–33.8	–36.0	.613	270	.862
[5]12	F.	4,000	54	1 30	34.0–34.0	.....	.989	399	.794
[6]2	F.	3,650	51	2 ..	34.5–35.0	33.4–	.909	422	1.012
[7]7	M.	3,200	50	2 ..	32.0–32.0	.....	.749	457	.909

[1]In this and the following tables only the experimental conditions which might be supposed to have interest are quoted. Therefore, the figures for the air analyses and the percentage of oxygen in the respiration chamber are not given. The latter, according to carbon-dioxide percentage, would be about 20 per cent.

[2]No food; during whole experiment very quiet; slept the latter half of experiment.

[3]No food; bath, crying and kicking for about a minute; otherwise contented, sucking or half asleep; thin.

[4]No food; quiet, now and then sucking; otherwise without movements during whole experiment; no crying.

[5]No food; rather restless, hungry; now and then crying; see No. 22, table 4.

[6]No food; during most of the experiment quiet and contented, now and then sleeping; cried about one-half minute; fat and strong.

[7]No food; rather quiet, now and then kicking and trembling as if cold; no crying.

In table 2 three pairs of experiments are reported, the subjects being fairly well-nourished infants, in all cases examined so soon after birth that the quotient still points towards a predominance of carbohydrate combustion. Table 2 shows that in all three instances the quotient fell considerably in the course of the hour between the first and the second division of the experiment, changing from a little above to a little under 0.9.

I made here the curious observation, which has been partly expressed in the remarks in the last column of the table: When a new-born fasting infant begins to show signs of hunger, we can be sure that its quotient is lower than 0.9; according to this indicating symptom the time for the beginning of the second half of the experiment is adjusted, and hunger

signs have appeared not only in these 3 experiments, but in about 10 instances where I have made observations on the fasting new-born infant. The child's customary sign of hunger, sucking its fingers or its hand, can most certainly be misunderstood, but not by a skilled observer. There is a considerable difference in the playful manner in which a satisfied and well-nourished infant temporarily sucks its fingers for lack of any other pastime, and the energy in a hungry child's strong sucking, which is either frequently interrupted by angry crying or is constant and hopeful.

The rule which is brought out by table 1, *i. e.*, that the respiratory quotient is nearer 1.00 the better the condition of the infants, is not contradicted by table 2. The child in experiments 19 and 20 with the fairly normal weight of 3,600 grams and the unusual length of 54 cm. had a very marked birth swelling at the crown of the head; its real length was barely over 51 cm.; and it is inaccurately recorded in the remarks accompanying the table "good condition."

Table 2 brings out a second point: *The respiratory quotients are nearer 1 the sooner after birth the infant is experimented upon.*

TABLE 2.

Experiment No.	Sex.	Body-weight.	Height.	Age.	Temperature of air in apparatus.	Body-temperature (rectal).	Carbon dioxide in air of chamber.	Carbon-dioxide elimination per kilogram per hour at 0° C. and 760 mm.	Respiratory quotient.
		gm.	*m.*	*hr. m.*	*°C.*	*°C.*	*p. ct.*	*c.c.*	
[1]17	M.	3,400	52	30	34.3–34.0	36.2–	0.678	344	0.933
[2]18				1 45	34.5–34.5	–37.3	.568	275	.854
[3]13	M.	4,500	53	45	34.2–34.8	36.8–	1.332	488	.921
[4]14				1 45	33.5–33.5	–37.4	.775	300	.808
[5]19	M.	3,600	54	1 30	33.5–33.3	33.9–35.2	.605	400	.921
[6]20				2 30	32.5–32.5	35.2–35.8	.490	306	.849

[1]No food; no bath; wide awake; quite contented; no crying.
[2]Hungry and sleepy in last two-thirds of experiment; frequently sleeping, constantly awakened; no crying.
[3]No food; no bath; awake and contented.
[4]Sleeping quietly during nearly the whole experiment.
[5]No food; bath; good condition; considerable birth swelling; lively and contented; later hungry and somewhat sleepy.
[6]Stupid; fell asleep now and then, but awake most of the time; cried 1 minute; at the last lively.

A well-nourished infant, born at full term, has a store of carbohydrate which it lives on either exclusively or largely in the first hours of its life; gradually this store (which consequently can not be especially large) is used up, and this leads to an increase in the oxidation of the other elements.

In table 3 five experiments are given with 4 under-weight, prematurely-born infants. The experiments indicate that such infants show signs of being very poorly nourished, in that their carbohydrate store is very quickly spent. But if the infant is experimented upon soon

enough after birth (as in experiments 10 and 11, in which the infant was placed in the respiration chamber immediately after tying the navel cord) we see clearly that here also we have to deal with the consumption of a store of carbohydrate, which causes the organism to burn other materials in addition.

In experiment 6 the quotient, even within an hour after birth, is 0.766. Experiment 11 serves well for comparison. In this experiment an infant of the same length, but weighing 200 grams more, shows a quotient of 0.897 an hour after birth. If experiments 10 and 11 are compared, we find in the case of prematurely-born children, also, the same influence of condition of nutrition and of interval of time after birth upon the quotient as with those born at full term.

TABLE 3.

Experiment No.	Sex.	Body-weight.	Height.	Age.	Temperature of air in apparatus.	Body-temperature (rectal).	Carbon dioxide in air of chamber.	Carbon-dioxide elimination per kilogram per hour at 0° C. and 760 mm.	Respiratory quotient.
		gm.	*cm.*	*hr. m.*	°*C.*	°*C.*	*p. ct.*	*c.c.*	
[1]6	M.	2,550	47	1 ..	33.0–33.5	.....	0.524	339	0.766
[2]5	F.	1,825	44	2 ..	34.5–34.5	33.4–35.8	.392	273	.871
[3]4	M.	2,700	50	1 30	–33	33.1–35.0	.729	464	.858
[4]10	M.	2,750	47	15	35.3–35.2	36.5–	.561	462	.912
[5]11	M.	2,750	47	1 ..	35.2–35.1	–37.8	.521	420	.897

[1]No food; quietly sleeping or sucking during the whole experiment.
[2]No food; bath; sleeping; respirations irregular, very few movements; artificial delivery; more than 1 month premature; died day following.
[3]No food; lively in first half of experiment, sleeping in last half; born less than 1 month prematurely.
[4]No food; no bath; born 3 weeks before time; crying about one-third of the time.
[5]Quieter; crying about one-fourth of the time.

The infant in experiment 5, although very poorly nourished, has a somewhat high quotient of 0.871, 2 hours after instrumental delivery. The fact that this child when 2 hours old still had a large quantity of carbohydrate to draw from is presumably due to the unusually low metabolism. This experiment is important; it is a case of premature interruption of pregnancy of more than a month before the end of the full term. The prematurely-born infant, therefore, shows the same respiratory quotient as the full-term child, indicating that it is consuming the remainder of its carbohydrate supply. It is an obvious supposition that during the fetal life in mammals, *with a physiological nourishment by the mother, there are always sufficient carbohydrates at hand, so that the respiratory exchange takes place normally with an exclusive metabolism of carbohydrates.*

This supposition of mine is well supported by literature. The fact that the fetal tissues contain large quantities of glycogen, which steadily diminish during growth (always excepting the liver, in which more and

more glycogen is stored), and the fact that the invertin[1] from the mucous membrane of the small intestine provides the fetus with a ferment for the eventual katabolism of this glycogen, are both arguments that point towards the important rôle of the carbohydrate in the economy of the fetus. Charrin and Guillemonat[2] find more glycogen in the liver of the pregnant guinea-pig than in the non-pregnant; *and this is true both during inanition and during a rich carbohydrate feeding.* In pregnant guinea-pigs this signifies, then, either an increased impulse towards preparing glycogen from its food material or, in case of need, from its own body elements. Furthermore, as already mentioned, Bohr has definitely shown that the respiratory quotient of the guinea-pig's embryo is 1.0, without reference to the fact that the respiratory quotient of the mother may be lower.

It may have been noticed that in most of the previous experiments the percentage of carbon dioxide in the respiration chamber was quite high, most frequently between 0.5 and 1.0 per cent. This was done in order that the unavoidable errors in the analyses would have less effect upon the results. That it is not this fairly high percentage of carbon dioxide which has caused the difference between my results and those of Scherer and Babák is evident from the fact that these scientists have worked with approximately the same percentage of carbon dioxide in the respiration chamber.

In the double experiments in table 2 the metabolism, *i. e.*, the carbon dioxide per kilogram and per hour, in the second half of the experiment is in every instance considerably less than in the first half of the experiment. This smaller metabolism, which was a result of the infant's sleepiness in the later period, has no modifying influence on the size of the quotient. The decreasing lung ventilation at the beginning of sleep could well be thought in the first minutes[3] to be followed by a slight drop in the quotient (if the relationship in this regard is the same as in adults, which is not proved), but in the course of the 23 minutes of the experiment in every case such an effect was soon compensated for. The experimental period is after all so long that we can judge of the nature of the oxidized material from the quotient without fearing to be misled by the influence of lung ventilation or work.

If we wish to be convinced that the quotients quoted above are not affected systematically (and therefore are unaffected) by work done during the experiment (crying, kicking, etc.) we need only to compare experiments like 2 and 9 in table 1 on the one hand and 3 and 8 in table 1, and 5 in table 3, on the other. The comparison between 3 and 8 is especially convincing; in 3 there is twice as great a metabolism as in 8, due to the difference in muscular activity, but the same quotient is found with both.

That the percentage of carbon dioxide in the atmosphere about the infant can not be considered to have an effect upon the quotient has already been quite definitely settled for adults by Speck's[4] experiments. In his experiments the same percentage of carbon dioxide as that used

[1]Miura, Zeitschr. f. Biol., 1895, **32.**
[2]Charrin and Guillemonat, Compt. rend. de la soc. de biol., 1900.
[3]Speck, Physiologie des menschlichen Athmens, Leipsic, 1892, p. 16. [4]Speck, *loc. cit.*, p. 133.

in these experiments is shown to bring about a decrease in the oxygen intake, and a consequent increase in the respiratory quotient, only when the oxygen percentage in the atmosphere is at the same time very low (*i. e.*, 8 per cent against 20 per cent in my experiments). This fact is strikingly demonstrated by a comparison of 12 and 2 in table 1 (with the same percentage of carbon dioxide and extreme difference between quotients) and a comparison of 13 in table 2 and 5 in table 3 (with an extreme difference between the percentage of carbon dioxide and approximately the same quotient).

As regards the amount of the metabolism in the above experiments it seems impossible for me to conclude anything else from the tables than that the activity of the infant is the chief determining factor, and that the influence of other conditions, such as the condition of nourishment, age, etc., is not demonstrated, at least by my method of experimentation. The influence of activity is overwhelming and is observed regularly in the double experiments in table 2, and 10 and 11 in table 3, in which the child in the second experiment is always either drowsy or asleep. In the single experiments, also, we find a striking parallelism between the amount of the metabolism recorded and the intensity of the activity. It is naturally quite difficult to judge of and to express in words the degree of strength with which the infant has contracted its muscles in the course of 23 minutes. In the experimental pairs 17–18 and 19–20 (table 2) I have repeatedly awakened the infants in the second experiment by rapping loudly on the cover of the respiration chamber. The purpose was to keep the activity and thereby the metabolism artificially at the same level as in the first experiment. Although the infants reacted to every rap with severe general contraction of the muscles, the drowsiness throughout the entire period has been the determining factor; the metabolism in experiments 19 and 20 fell 25 per cent.

Even though it is difficult to determine the work which the different children have done during the experiment and therefore difficult to arrive at a numerical expression for the effect of work on the amount of the metabolism, it is easy to convince one's self of the absolute absence of visible contractions. When such a condition has prevailed throughout the 23 minutes of the experiment we find a very low metabolism value—from 270 to 300 c.c. carbon dioxide per kilogram and per hour. *Such figures are found both for infants overweight (3,950 grams in experiment 8 of table 1, etc.) and for infants underweight (1,825 grams in experiment 5 of table 3, etc.).* After due reflection this is not surprising. The heat regulation of a new-born infant[1] is very poorly developed. Even if it were not poorly developed, the temperature during the experiment is so regulated that the question of the feeble heat regulation of the child is eliminated as far as possible. Thus every experimental condition which would produce a smaller metabolism per unit of weight in the large infant with a relatively small surface than in the smaller infant with a relatively large surface is eliminated. But there is cause for reflection in the fact that *a figure like 270 c.c. for the*

[1]Babák, Archiv f. d. ges. Physiol., 1902, **89**, p. 154.

carbon dioxide per kilogram and per hour for a new-born infant is not essentially higher than the corresponding figure for a grown individual in absolute repose.

There is reason to investigate whether the different temperatures of the children experimented upon have had an effect upon the difference in the amount of the metabolism. As previously mentioned, a fairly accurate value for the infant's temperature during the experiment is the last figure in the column headed "Body-temperature" in the tables. Recorded in this way, the infants' body-temperatures during the experiments do not show large differences, and these are in all instances plainly not parallel with the differences in the amount of the metabolism; I emphasize experiment 3, table 1 (temp. 35.2°, metabolism 481), in comparison with experiment 8, table 1 (36.0°, 270); experiment 5, table 3 (35.8°, 273) with experiment 4, table 3 (35.0°, 464), etc. Moreover, it is sufficiently well known that strong and continuous crying can raise an infant's temperature about 0.5°. As crying is followed by a rise in metabolism, a certain degree of parallelism between the infant's temperature and the figure for the metabolism was expected.

As regards the low temperatures after the birth-bath, they are for full-term and strong infants obviously considerably lower than is considered the rule. Vierordt[1] reports a temperature fall on account of birth and birth-bath at an average of 1° C; a fall of 1.7° C. "comes very rarely," but with delicate infants it may amount to even 4.7° C.

In my experiments the normal children in experiments 3 and 2 in table 1 show in one-half hour and 2 hours after birth a temperature which is 4° C. or more below normal. When no bath after birth was given prior to the experiment, the cooling-off after birth has been followed by a fall in temperature of about 1° C. (experiments 17 and 13 in table 2 and experiment 10 in table 3). I would not dispute the fact that the tepid birth-bath is in all cases a very important means of reflexly starting the respirations, but I consider it very possible that the cooling off brought about by the bath can be carried too far, and if special arrangements have not been made for effectively warming the child after the bath, the cooling effect can be of too long duration.

How is the respiratory metabolism of the new-born infant altered under the influence of food, as well with respect to the quotient as to the amount of the metabolism? When a hungry individual is put on a nearly exclusive carbohydrate diet,[2] his respiratory quotient reaches 1 about an hour after the first meal. In the course of an hour, therefore, the absorption and combustion of the carbohydrates in the different organs is in full operation. If we make an experiment similar to this with fat, the quotient shows that the time for the combustion of fat is considerably longer, *i. e.*, about 3 hours after eating; something similar is true of proteids. Carbohydrates, therefore, are for grown individuals the food element most easily and most quickly consumed. This agrees very well with the fact that Mosso found with dogs an increase in temperature of about 1° C. an hour after taking 1 to 2 grams

[1]Vierordt, Physiol. d. Kindesalters, 1877, pp. 152–154.

[2]Speck, Physiologie des menschlichen Athmens, Leipsic, 1892, p. 35; Magnus-Levy, Archiv f. d. ges. Physiol., 1894, **55**, p. 1.

of cane sugar per kilogram of the dog's body-weight. From the records of the body-temperature of the dog during and after a meal, consisting of cane sugar or of isodynamic quantities of bread, Mosso concludes that about an hour after taking the sugar is all absorbed, small quantities being used entirely for the formation of heat and larger deposits being used in part for the same purpose and in part stored for future consumption. Bread is utilized in the same way, but more slowly, since it takes longer before the other food elements in the bread are oxidized. The bread as a whole, therefore, can not develop a heat influence so suddenly as can isodynamic quantities of sugar.

TABLE 4.

Experiment No.	Sex.	Body-weight.	Height.	Age.	Temperature of air in apparatus.	Body-temperature (rectal).	Carbon dioxide in air of chamber.	Carbon-dioxide elimination per kilogram per hour at 0° C. and 760 mm.	Respiratory quotient.
		gm.	*cm.*	*d. hr.*	*°C.*	*°C.*	*p. ct.*	*c.c.*	
[1]25	M.	3,600	..	5 ..	33.0–33.0	36.5–37.0	1.148	510	0.930
[2]22	F.	4,100	54	5 ..	31 –31	36.0–36.8	1.133	487	.916
[3]21	M.	3,250	52	2 ..	32.0–32.0	35.2–36.8	.851	478	.799
[4]24	M.	3,400	52	5 ..	32.3–32.7	35.4–36.6	.743	395	.807
[5]15	F.	1,900	..	5 ..	33.5–33.8	.....	.260	205	.770
16					33.4–33.7	.....	.373	235	.806
[6]28	M.	3,000	50	.. 15	32.5–32.5	37.0–37.0	.707	482	.849
[7]30	F.	2,950	..	1 ..	31.8–32.5	36.8–37.0	.894	642	.872
[8]23	F.	2,550	..	.. 15	32.0–32.0	34.4–34.6	.449	283	.691

[1]Breast-fed 1 hour before experiment; cried somewhat for about 8 minutes; passage of urine and feces; during the last 5 minutes asleep. See experiment 27, table 5.

[2]Breast-fed; same as subject in experiment 12, table 1; breast-fed 1 hour previously; awake and satisfied.

[3]Same as subject in 17 and 18 in table 2; slight jaundice; breast-fed 2 hours previous to experiment; cried 3 minutes; awake and lively, sucking its fingers.

[4]Breast-fed 2 hours and again just before experiment; asleep or drowsy; only a few movements; no signs of hunger.

[5]Incubator infant; weighed at birth 1,950 grams; takes to the breast poorly; is put to the breast every 2 hours; last time just previous to experiment; fast asleep. This applies to experiment 16 as well.

[6]Bottle and breast; last meal 3 hours and again just previous to experiment; awake and lively. See experiment 29, table 5.

[7]Breast; last meal 3 hours and again just before experiment; violently crying more than two-thirds of the time; rest of the time in light sleep. See experiment 31, table 5.

[8]Breast; born 2 to 3 weeks prematurely; breast-fed altogether 2 times, 5 hours before and again just before experiment; took to breast well; absolutely quiet, half and wholly asleep.

An individual on a liberal mixed diet does not show variations in the respiratory quotient which would suggest a selective choice of the different foodstuffs. For instance, he does not have an hour after a meal a respiratory quotient of 1, 2 hours after a quotient of 0.8, and 3 hours after 0.7, but would, at any time selected, have a quotient which varies but little from 0.88, for example. The reason for this is that the nourishment is plentiful, or, in other words, that there is in the circulation almost the same mixture of all three chief nutrients or their

intermediate metabolism products. Meals, which as a rule follow so quickly after each other that the fat and albumin absorption in the course of a day does not cease at all, can therefore not have any recognizable influence on the quotient. The evident conclusion is that if a meal (having constant composition) causes variations in the quotient of the above-mentioned character, it must mean that the nourishment is insufficient. I am not certain whether experiments favor this conclusion, but I do not doubt that the supposition is true in the case of the adult.

The meal affects the amount of the metabolism in such a way that the activity of the muscles and of the glands, caused by the ingestion of the food, increases the respiratory metabolism about 10 per cent. If we consider table 4, in which the experiments are arranged according to the time which has elapsed after the last meal, there seems to be little doubt concerning the effect of the meal on the respiratory quotient. In the two experiments (25 and 22) which began an hour after the meal, the middle of the experiment corresponding to $1\frac{1}{2}$ hours after the meal (intervals which are important in carbohydrate metabolism), high quotients are found, namely, 0.930 and 0.916. These quotients point towards a predominant carbohydrate metabolism. In experiment 21 the meal was given 2 hours previous and the quotient is 0.799. Almost the same quotient was found in experiment 24 (0.807). Previous to this experiment the child had not been fed for 2 hours, but was put to the breast just before the experiment began. The preceding meal may, therefore, be considered as having increased the metabolism but not as having changed the quotient, because at the end of the experiment only 38 minutes had elapsed since the meal (15 plus 23 minutes). The metabolism during the experiment was the metabolism of the elements from the previous meal. The exact correspondence between the quotients in these two experiments also seems to indicate that the metabolism of the food given just before experiment 24 did not begin during the experimental period.

Experiments 15 and 16, with a 5-day-old incubator child for subject, are interesting because they point towards the time when the metabolism of a meal begins; they were conducted at 1-hour intervals. The child received its last meal 2 hours before experiment 15, and therefore in this experiment has a quotient of 0.770 (approximately the same as the quotient in 21 and 24). With experiment 16, however, the child had its last meal an hour previous to the beginning of the experimental period; we therefore find an increased quotient, *i. e.*, 0.806.

In experiments 28 and 30, both with infants fed at the breast 3 hours previous to and again just before the experiment, quotients of 0.849 and 0.872 were obtained, which again show fair uniformity. These quotients are considerably lower than those obtained one-half hour after the meal, but higher than those obtained 2 to $2\frac{1}{2}$ hours after. This may be only accidental, but it is impossible to decide concerning this point. If we determine the metabolism 5 hours after the meal, as in experiment 23, the quotient is found to be 0.691, indicating the katabolism of fat.

It is quite clear to me that in investigating these circumstances it would have been experimentally more correct to have used the same instead of different infants. The material for the investigations, however, was collected for another purpose. Nevertheless the dependence of the respiratory quotient upon the interval of time elapsing after the last meal is shown in table 4, and in such a striking manner that there can hardly be any other interpretation.

There is, however, no doubt about one point. Even though the composition of the food of the infant is much more constant than that of the adult, the respiratory quotient of the infant varies continually with the meals, so that it is highest about $1\frac{1}{2}$ hours afterwards (during this period the metabolism of lactose is chiefly going on), and very low about 5 hours after, when the lactose from the last meal had been used up. I would not insist that this is definitely in favor of more frequent feeding than the ordinary 5 feedings during the course of the day, but it certainly deserves some consideration.

On the other hand, it is possible that it might be harmful to the infant if the meals were so near together that the respiratory quotient remained constant throughout the day. In any case the problem is interesting and deserves a more thorough investigation, especially in the case of the same child throughout a rather long interval of time, with varying frequency of feeding with the same quantity of food and under constant control of the weight curve.

Table 4 does not give any new information concerning the amount of the metabolism. The influence of activity is also quite apparent here. The premature incubator infant in experiments 15 and 16, which was practically motionless during the experiments, has a metabolism even lower than that found in the experiments with infants immediately after birth; it is interesting to note that the metabolism rises in the second experiment (both the carbon dioxide produced and the oxygen consumed), because this is supposedly to be interpreted in the same manner as the rise of the quotient in experiment 16. The work of digestion is greater in experiment 16 than in experiment 15. At any rate, it was impossible to recognize a difference in the muscular activity of the infant in the two experiments, as the child was lying relaxed and asleep. The quotients for the infants spoken of as "lively and content" are somewhat higher than those of similar cases in tables 1, 2, and 3; but it is also striking how much more energy is displayed by the child a few days old than by the new-born infant, exhausted after birth.

In experiment 30 we find an enormous metabolism, 642 c.c. of carbon dioxide per kilogram and per hour; but in this case we observe that the child was "violently crying more than two-thirds of the time." Evidently we can not overestimate the increased metabolism due to the incessant crying of feeble infants.

Experiment 27 (not given in the tables) illustrates the effect of crying on the amount of the metabolism. By moderately lowering the temperature (which caused a drop in the body-temperature of 0.4° C.) we succeeded in making the child cry very violently for about 17 min-

utes. The experiment was made with the same male infant as experiment 25 in table 4, the weight of the child being 3,600 grams and the age 6 days. It was breast-fed. The temperature of the apparatus was 25° to 26° C.; the body-temperature of the infant was 37.0° to 36.6° C. The percentage of carbon dioxide in the air of the chamber was 1.534; the carbon-dioxide elimination per kilogram per hour, reduced to 0° C. and 760 mm., was 764 c.c. and the respiratory quotient 0.897. The child was crying violently three-quarters of the experimental period and was evidently cold. In the middle of the experiment there was a quiet period with a little sobbing. It would be erroneous to consider the great increase in metabolism (compare experiment 25, table 4) in this experiment a result of the child's "chemical heat regulation" brought about by a cold reflex.[1] The infant would have reacted to any other equally powerful irritant with as severe crying and with equally high metabolism.

Even if the previous experiments leave no doubt that the carbohydrates of the food play the same rôle in the infant's nutrition as in that of adults, namely, that of the most accessible food elements and consequently most quickly consumed for heat production, and even if the results in table 4 are most easily interpreted on the supposition that the absorption and metabolism of carbohydrates reach their climax 1 to $1\frac{1}{2}$ hours after the meal, further experimental evidence is still needed of the correctness of this hypothesis. With this purpose in mind three infants were put on a diet so arranged that meals were given between their regular feedings. These meals consisted of 4 to 5 grams of grape or milk sugar dissolved in a little water.

In experiment 29 of table 5 the respiration experiment commences 3 hours after the milk meal and about $1\frac{1}{2}$ hours after the lactose meal. The quotient is 1.0. In experiment 26, in which the grape sugar was given 4 hours and again one-half hour previous to the experiment (breast-feeding between the two feedings about 2 hours previous to the experiment), it is seen that the quotient 0.869 does not point towards an exclusive carbohydrate metabolism. *In the course of the half hour the absorption of the administered grape-sugar has not taken place.* Finally, in experiment 31, undertaken about $3\frac{1}{2}$ hours after the last milk meal and about $2\frac{1}{2}$ hours after the last grape-sugar feeding, the quotient is 0.845, *an index that the metabolism of the 4 grams of grape-sugar has to a great extent taken place as quickly as $2\frac{1}{2}$ hours after administration.*

This result corresponds strikingly with those obtained by Speck and Magnus-Levy with adults (my discussion of the results in table 4 were based on the results obtained by these two authors), and with Mosso's demonstration of a temperature rise of 1° C. in the case of a starving dog, about an hour after the ingestion of an amount of sugar corresponding to that used in these experiments. It is thus clear that the custom of feeding sugar-water immediately after the birth-bath rests upon a

[1]Babák (Archiv f. d. ges. Physiol., 1902, **89**, p. 166) interprets a rise in metabolism from 332 c.c. to 579 c.c. carbon dioxide as a sign of an "auffällige Thätigkeit der chemischen Regulation," without giving information about the child's behavior in the two cases.

very sound principle. Of all the elements of nutrition sugar is digested by the infant the most quickly and the most easily, and doubtless causes a rise in temperature very much to be desired, because of the cooling-off at birth and during the birth-bath.

Experiment 1 of table 5 is an experiment which should illustrate this utilization of sugar, but there are some objections. In the first place, it was not wise to select a period 3 hours after birth for feeding with sugar; in the second place, it will always be difficult to demonstrate in respiration experiments the utilization of sugar at such a period, for even without sugar the quotient at this period is close to 1.0. But a direct demonstration of this point is unnecessary. The fact that the small intestine of the fetus contains invertin shows that it is equipped for the digestion of carbohydrates, and therefore favors the supposition that the new-born infant should be able to digest cane-sugar without difficulty immediately after birth.

TABLE 5.

Experiment No.	Sex.	Body-weight.	Height.	Age.	Temperature of air in apparatus.	Body-temperature (rectal).	Carbon dioxide in air of chamber.	Carbon-dioxide elimination per kilogram per hour at 0° C. and 760 mm.	Respiratory quotient.
		gm.	*cm.*	*d. hr.*	*°C.*	*°C.*	*p. ct.*	*c.c.*	
[1]29	M.	2,950	50	2 ..	31.8–32.1	36.4–36.5	0.806	617	1.027
[2]26	F.	2,450	..	2 ..	31.8–32.1	36.0–35.7	.553	370	.869
[3]31	F.	2,950	..	2 ..	31.0–31.3	36.3–36.7	.511	343	.845
[4]1	F.	3,700	51	.. 3	33.5–35.0	34.2–35.4	1.291	500	.902

[1]Bottle and breast; same as subject of experiment 28 in table 4; in last 24 hours between the meal-times fed with 5 × 4 grams milk-sugar, last time 1¼ hours before experiment. Crying violently for 4 minutes, afterwards half or wholly asleep.

[2]Breast; same as subject of experiment 23 in table 4; in last 36 hours 5 × 5 grams grape-sugar, last 4 hours and ½ hour before experiment; sleeping or dozing; now and then vigorous movements.

Breast; same as subject of experiment 30 in table 4; in the last 24 hours 5 × 4 grams grape-sugar; last feeding 2¼ hours before experiment; half or wholly asleep.

[4]Sugar-water at birth; bath; crying about one-half of the time; otherwise restless, kicking, and perspiring.

It would be unreasonable to dispute the fact that mother's milk is the ideal nourishment for the infant. It is well to note, however, that the infant must be born at full term and be healthy. With premature infants and infants with intestinal catarrh or other digestive ailments, which result in diarrhea and rapid loss of weight, it is quite a different matter.

Recent investigators in this line tend more towards localizing the logical cause of digestive diseases in those organs in which the final katabolism of the food elements takes place, instead of in the mucous membrane of the digestive tract and the accessory digestive glands; indeed, there are many points which favor a pathological retarded development of the oxidative functions of the liver tissues.

Meinhard Pfaundler[1] has shown in an interesting paper that *an infant, and especially an infant weakened from some illness, is unable to oxidize the fat and albumin in the nourishment as completely as the adult,* and he has shown by experiments that this is due to some extent to the small oxidative power of the liver tissue.

Carbohydrates receive a prominent place as that constituent in milk which is most easily and most completely oxidized under all conditions, and which is therefore an important element in the feeding of the infant, whose fat and albumin digestion is supposedly overworked. In such cases the mother's milk is not the ideal food, for its contents of fat and albumin (which can not be digested and whose products of decomposition may do harm in the intestine) are altogether too large and cause the child in reality to starve.

In reviewing the extensive amount of literature on artificial feeding of atrophic infants, it is evident that the composition which has had the best results, Keller's malt soup (a modified Liebig soup), points towards feeding largely with easily digested carbohydrates (maltose). With this kind of feeding the formerly atonic and poorly-nourished infant thrives and the disease is, as a rule, cured at one stroke. If, therefore, it is demonstrated that mother's milk is not the most favorable nourishment in all pathological cases, it is well, bearing the previous results in mind, not to take it for granted that mother's milk is indicated in the case of the premature infant, but to consider whether feeding with relatively large amounts of carbohydrates would not be preferable.

Conclusions.

I. The well-nourished infant, born at full term, has a store of carbohydrates (glycogen) in its organs, which is spent in the course of a few hours.

II. The metabolism of a poorly-nourished and premature infant depends chiefly on the oxidation of carbohydrates during the first hours of life.

III. There is every reason to suppose that the metabolism of the normal, well-nourished human fetus consists of the oxidation of carbohydrates.

IV. When the infant is fed with mother's milk, the respiratory metabolism shows a mixed quotient, which varies with the meals in such a way as to indicate that milk sugar is the element most quickly burned, that is, about $1\frac{1}{2}$ hours after the meal. This fact is confirmed by experiments.

V. The amount of the infant's metabolism is to a very large extent dependent upon muscular contractions. At 32° C. and with least possible work, the metabolism per kilogram is hardly greater than that of the adult at absolute rest.

VI. The relative ease with which carbohydrates are digested favors their extensive use in cases where the ability to digest the other constituents of human milk is decreased.

---

[1]Meinhard Pfaundler, Jahrb. f. Kinderheilk., 1901, **54**, p. 247. See also here a large amount of literature on the subject.

DISCUSSION OF HASSELBALCH'S RESEARCH.

We consider it peculiarly unfortunate that in our two earlier publications reference to Hasselbalch's research and to his striking conclusions was inadvertently omitted, and although at that time we were unable to comment intelligently upon the results or make a satisfactory abstract of them, since there were some difficulties in the translation, nevertheless it would have been desirable to call attention earlier to the existence of this wholly remarkable piece of research upon infant metabolism. Although the study was made 11 years ago, the same degree of care and nicety of technique which has characterized Hasselbalch's subsequent observations is apparent in this research. It is obvious that we have here for the first time quantitative measurements of the gaseous metabolism of infants by a study of the carbon-dioxide increment and oxygen deficit in the ventilating current of air. It is an interesting fact, which should certainly be pointed out, that the apparatus used by Hasselbalch for this study embodied the same principle as the Jaquet[1] apparatus, and, indeed, both forms of apparatus were described in the same year, thus proving independent simultaneous development.

Of particular importance in studying the respiratory exchange is a special appreciation of the significance of the difficulties of determining the oxygen in any gaseous mixture, even in ordinary atmospheric air. Researches in the Nutrition Laboratory have shown that the external air is of absolutely constant composition, irrespective of seasons, wind direction, weather conditions, barometric pressure, and altitude.[2] Consequently it can be assumed that any gas-analysis apparatus which fails to give constant values for the oxygen content of the atmospheric air may be considered on this *a priori* evidence as being an inaccurate apparatus, or the technique is at fault.

It is, furthermore, obvious that the greater the carbon-dioxide increment and the greater the oxygen deficit in the ventilating current of air, the less the analytical errors will influence the calculation of the respiratory quotient. It has been frequently pointed out that those using the Jaquet method are too often inclined so to adjust the ventilating air-current as to have a minimum carbon-dioxide increase and an equivalent oxygen deficit. When this carbon-dioxide increment is less than 0.5 per cent, analytical errors play a great rôle not only in the calculation of the respiratory quotient, but likewise to a certain extent in the calculation of the total metabolism. Since the analytical errors in the determination of the carbon dioxide are very much less than those in determining oxygen, this may not of necessity be a serious matter. On the other hand, the exact determination of oxygen necessitates the skill of the best trained analyst and an especially accurate gas-analysis apparatus with a carefully controlled technique. When the oxygen

[1]Jaquet, Verhandl. d. Naturforsch. Gesellsch. in Basel, 1904, **15**, p. 252.
[2]Benedict, Carnegie Inst. Wash. Pub. No. 166, 1912.

deficit is less than 0.7 per cent, analytical errors of plus or minus 0.03 per cent (which are not at all infrequent) will have a very considerable influence upon the computations of the respiratory quotient.

The air analyses published by most users of the Jaquet apparatus have shown discrepancies in the oxygen content of external air which lead one to suspect analytical errors. We note with interest, however, Hasselbalch's statement regarding his own experience in analytical analysis, which indicates that he found very insignificant variations in the composition of the atmosphere. Thus we may properly infer an especially careful analytical procedure. But of more significance is the fact that Hasselbalch's published results show us that his carbon-dioxide increment was frequently 1 per cent or even 1.5 per cent. It is clear that Hasselbalch's analytical data are probably as accurate as any determinations thus far made of the carbon-dioxide increment and the oxygen deficit in an open-circuit respiration apparatus, and we may have an unusual degree of confidence in his values.

The number of infants studied by Hasselbalch was too few to obtain definite physiological constants, and although he reports 31 experimental periods on 20 infants, and as a result of his accurate technique was able to make deductions from them, it is obvious that a problem so important as the metabolism during the first week of life demands not simply confirmation but further elaboration of data. We shall have occasion, in discussing our own results subsequently, to refer to the sharply drawn conclusions reported by Hasselbalch.

OBSERVATIONS BY WEISS.

In 1908 G. Weiss,[1] employing a type of respiration apparatus which was entirely different from those previously used for studying infant metabolism, made a most interesting series of observations on new-born infants, in which both the carbon-dioxide output and oxygen intake were studied. Twelve new-born infants were observed, ranging in age from 1 to 11 days. His apparatus consisted of a metal chamber supplied with a window and a thermometer, and having a capacity of 60 liters. The infant was hermetically sealed in this chamber and remained there for approximately an hour. The air in the chamber was then thoroughly mixed by an electric fan and a sample taken for analysis. This method of studying the gaseous exchange was employed by Chauveau and Kaufmann and used with especial success by Laulanié. The carbon-dioxide increment in the chamber and the oxygen deficit could be readily computed from the results of the analysis and data obtained as to the total oxygen absorption and carbon-dioxide production of the infant.

The author points out that with new-born infants the carbon-dioxide excretion is two, three, or sometimes four times greater per kilogram of body-weight than it is with the adult. He found, for example, that the carbon dioxide excreted varied from 1,064 c.c. to 337 c.c. per kilogram

[1] G. Weiss, Bul. de l'Acad. Méd., 1908, **60**, 3d ser., p. 458.

per hour, while the values for the oxygen consumed varied from 1,248 to 404 c.c. per hour. He also states that he found the respiratory quotient to be generally much higher than the results obtained by Scherer. Basing his discussion upon the law of surface area, Weiss concludes that the metabolism is proportional to the cube root of the square of the weight. We give here his argument in full. His results are given in tables 6 and 7.

La consommation de divers sujets de même espèce, et les phénomènes qui l'accompagnent, en particulier l'intensité des échanges respiratoires, doit donc être proportionnelle à $\sqrt[3]{P^2}$, et en rapportant cette consommation à l'unité de poids, on obtient $\frac{\sqrt[3]{P^2}}{P} = \frac{1}{\sqrt[3]{P}}$, que je désignerai par α.

Si donc tous les sujets se trouvaient dans les mêmes conditions d'utilisation d'oxygène, ils devraient, par kilogramme, faire une consommation proportionnelle à α. En désignant l'oxygène absorbé par kilogramme-heure par Q, $\frac{Q}{\alpha}$ serait constant, quelle que soit la taille du sujet. En suivant les variations de $\frac{Q}{\alpha}$, on a réellement l'indication d'une utilisation surabondante ou défectueuse de l'oxygène; c'est pourquoi ce rapport peut être désigné par le nom *d'indice d'oxygénation*. Cet indice d'oxygénation est en somme le rapport de ce qu'un sujet prend réellement d'oxygène à ce qu'il devrait prendre normalement pour sa taille.

En appliquant cette formule à l'adulte pendant le cycle de vingt-quatre heures, P étant exprimé en kilos et Q en litres, on obtient un indice voisin de l'unité; 0.99 à 1.03, pour l'homme variant de 60 à 70 kilogrammes.

Voyons maintenant ce que l'on trouve chez le nourrisson.

J'ai calculé les indices correspondant à mes diverses déterminations chez le nouveau-né; les résultats sont reportés dans la Table II. On ne constate plus alors cet écart considérable entre le nourrisson et l'adulte.

Dans les premiers jours après la naissance, l'indice d'oxygénation est un peu inférieur à la normale, mais il se relève ensuite et ne la dépasse guère; chez un seul sujet particulièrement beau il s'est élevé à 1.5 et meme 1.8. Mes mesures ne comprennent pas les premières heures, il y a là une lacune à combler.

Mais si, chez les enfants que l'on peut qualifier de normaux, c'est-à-dire qui augmentent régulièrement de poids, l'indice d'oxygénation prend une valeur un peu supérieure à l'unité, chez les débiles élevés à la couveuse il est franchement au-dessous, il est au voisinage de 0.5 et ne se relève pas; c'est là un point qui me paraît important et qu'il y a lieu d'examiner de plus près au moyen de nouvelles expériences.

Peut-être devrais-je m'arrêter ici et me contenter des constatations que j'ai faites; mais il y a lieu de se demander à quoi tiennent les différences d'indice que j'ai relevées.

Je ne voudrais pas sortir des limites de la physiologie normale et pénétrer sur un terrain peu sûr pour moi; cependant je tiens à faire une remarque qui peut orienter les recherches à entreprendre.

Jusque dans ces derniers temps, et conformément à la théorie de Lavoisier, la question de l'absorption d'oxygène par les êtres vivants était, sans restriction aucune, intimement liée à la production de l'énergie utilisée par les animaux.

Dans cet ordre d'idées on aurait pu se demander si certains enfants ne s'oxygènent pas plus que d'autres parce que, étant plus robustes, ils s'agitent et dépensent davantage.

Mais cette explication ne peut pas nous contenter; on a vu en effet plus haut que les robustes l'emportent sur les débiles même alors que les premiers dorment au repos complet et que les seconds s'agitent. En dehors de l'influence de l'agitation, il faut chercher une autre cause à la variation de l'indice d'oxygénation.

Au cours de recherches que je poursuis depuis plusieurs années, et dont j'ai publié quelques résultats à la Societé de Biologie, j'ai montré que non seulement, comme on le savait, certains animaux pouvaient vivre un certain temps à l'abri de l'air, y produisant du travail avec élimination d'acide carbonique, mais que cette production de travail ne se faisait pas aux dépens de provisions d'oxygène tirées antérieurement de l'atmosphère.

Le muscle peut travailler sans intervention de l'oxygène de l'air. Celui-ci ne semble intervenir que pour éviter l'encombrement de l'organisme par des déchets et produits toxiques. Autrement dit, l'oxygène est un épurateur.

Il se peut qu'il y ait lieu de rapprocher ce rôle épurateur de l'oxygène des bonnes conditions de développement des enfants robustes, tandis qu'il est insuffisant chez les débiles.

TABLE 6.[1]

Nos.	Age.	Poids.	CO_2	O_2	R. Q.	Remarques.
			I. ♀ BON ÉTAT.			
1	5e jour.	3.120	0.960	1.067	0.90	22°. Vient de téter. Cris fréquents.
2	.....	.....	0.887	0.935	0.95	22.5°. Cris fréquents.
3	.....	.....	0.975	1.023	0.95	23.5°. Cris fréquents.
4	.....	.....	1.064	1.248	0.90	24°. Cris fréquents.
5	8e jour.	3.370	0.922	0.971	0.95	21°. Tété il y a 2 h. 30. Cris fréquents.
6	.....	.....	0.884	0.912	0.97	21.5°. Vient de téter.
7	.....	.....	0.556	0.598	0.93	21.5°. Repos complet.
			II. ♂ BON ÉTAT.			
8	2e jour.	3.300	0.403	0.498	0.81	21°. Aucune tétée encore. Sommeil.
9	.....	.....	0.530	0.631	0.84	21.5°. Quelques cris.
10	4e jour.	3 270	0.604	0.695	0.87	21°. Vient de téter. Sommeil.
11	.....	.....	0.613	0.730	0.84	Sommeil.
12	7e jour.	3.420	0.701	0.779	0.90	22°. Vient de téter. Repos et sommeil.
13	.....	.....	0.753	0.801	0.94	23°. Sommeil.
14	9e jour.	3.520	0.659	0.701	0.94	23.5°. Vient de téter. Sommeil.
15	.....	.....	0.756	0.796	0.95	26°. Cris, puis sommeil.
16	11e jour.	3.620	0.815	0.886	0.92	24°. Vient de téter. Cris. Demi-sommeil.
17	.....	.....	0.837	0.854	0.98	24.5°. Demi-sommeil.
			III. ♀ BON ÉTAT.			
18	2e jour.	3.570	0.403	0.504	0.80	24°. Vient de téter. Sommeil.
19	.....	.....	0.413	0.504	0.82	25°. Sommeil.
20	4e jour.	3.600	0.407	0.509	0.80	23°. Vient de téter. Sommeil.
21	.....	.....	0.525	0.610	0.86	25.5°. Cris et sommeil.
22	6e jour.	3.710	0.629	0.732	0.86	24.5°. Vient de téter. Cris et sommeil.
23	.....	.....	0.596	0.678	0.88	26°. Cris et sommeil.
24	9e jour.	3.860	0.696	0.757	0.92	22°. Pas tété ce matin. Sommeil. Réveil. Cris.
25	.....	.....	0.589	0.685	0.86	22°. Tétée. Sommeil.
			IV. ♀ BON ÉTAT.			
26	2e jour.	3.050	0.469	0.579	0.81	22.5°. Aucune tétée encore. Sommeil.
27	.....	.....	0.579	0.697	0.83	24°. Réveil et pleurs.
28	4e jour.	2.780	0.479	0.614	0.78	23°. Vient de téter. Sommeil.
29	.....	.....	0.451	0.609	0.74	24°. Sommeil.

[1]Table I in the Weiss artiele.

TABLE 6[1]—Continued.

Nos.	Age.	Poids.	CO_2	O_2	R. Q.		Remarques.
			[2]V. ♂ JUMEAU DÉBILE À LA COUVEUSE.				
30	4e jour.	1.570	0.443	0.554	0.80	23.5°.	Légère agitation et sommeil.
31	6e jour.	1.530	0.337	0.481	0.70	24.5°.	Sommeil.
32	9e jour.	1.470	0.408	0.517	0.79	25°.	Légère agitation et sommeil.
33	11e jour.	1.480	0.364	0.444	0.82	23.5°.	Sommeil léger avec fréquents mouvements.
			VI. ♂ BON ÉTAT.				
34	2e jour.	3.070	0.403	0.492	0.82	24.5°.	Pas tété ce matin. Sommeil.
[3]35	5e jour.	2.900	0.401	0.521	0.77	26°.	Vient de téter. Sommeil.
			VII. ♂ BON ÉTAT.				
36	2e jour.	2.470	0.406	0.556	0.73	24.5°.	Aucune tétée encore. Sommeil léger.
37	4e jour.	2.250	0.551	0.771	0.72	25.5°.	Petite tétée le matin. Demi-sommeil.
38	7e jour.	2.320	0.556	0.670	0.83	23°.	Vient de téter. Sommeil.
39	9e jour.	2.370	0.565	0.698	0.81	23°.	Tété il y a trois heures. Quelques cris. Sommeil.
40	11e jour.	2.430	0.685	0.753	0.91	21°.	Quelques pleurs. Sommeil.
			[4]VIII. ♀ NÉ À 8 MOIS. DÉBILE. COUVEUSE.				
41	4e jour.	1.860	0.425	0.518	0.82	23.5°.	Cris la moitié du temps.
42	6e jour.	1.850	0.349	0.459	0.76	25°.	Quelques pleurs. Sommeil.
43	8e jour.	1.790	0.514	0.591	0.87	23.5°.	Sommeil et cris.
			IX. ♀ BON ÉTAT.				
44	1er jour.	3.200	0.342	0.433	0.79	26°.	Sommeil continu.
45	3e jour.	3.000	0.341	0.421	0.81	27°.	Vient de téter. Sommeil continu.
46	5e jour.	3.030	0.555	0.646	0.86	27°.	Quelques cris. Sommeil.
47	10e jour.	3.150	0.638	0.701	0.91	23.5°.	Quelques cris. Sommeil.
			X. ♂ BON ÉTAT.				
48	1er jour.	3.700	0.404	0.481	0.84	25.5°.	Aucune tétée encore. Sommeil un peu agité.
49	4e jour.	3.450	0.447	0.552	0.81	23°.	Vient de téter. Sommeil.
50	6e jour.	3.530	0.545	0.641	0.85	23.5°.	Vient de téter. Demi-sommeil.
51	8e jour.	3.550	0.664	0.772	0.86	23°.	Vient de téter. Cris fréquents.
			XI. ♂ BON ÉTAT.				
52	2e jour.	3.600	0.543	0.647	0.84	23°.	Vient de téter. Réveil tranquille. Quelques cris.
53	4e jour.	3.450	0.521	0.606	0.86	23°.	Vient de téter. Sommeil.
54	6e jour.	3.550	0.625	0.680	0.92	24.5°.	Vient de téter. Vagissements et sommeil.
			[5]XII. ♂ DÉBILE À LA COUVEUSE.				
55	1er jour.	1.950	0.327	0.404	0.81	26°.	Aucune tétée encore. Sommeil.
56	3e jour.	1.800	0.381	0.465	0.82	26°.	Quelques mouvements. Sommeil.
57	5e jour.	1.800	0.351	0.423	0.83	26.5°.	Sommeil.
58	8e jour.	1.790	0.465	0.495	0.94	24°.	Vient de téter. Sommeil et quelques cris.
59	10e jour.	1.820	0.512	0.539	0.95	23.5°.	Vient de téter. Demi-sommeil et réveil.

[1]Table I in the Weiss article.

[2]La mère n'ayant pas assez de lait, cet enfant recevait en supplément sept repas de 30 grammes de lait stérilisé. Dernier repas trois heures avant l'expérience.

[3]La mère n'a pas permis la continuation des mesures.

[4]L'enfant tétait environ deux heures avant l'expérience.

[5]Jusqu'au huitième jour, cet enfant, trop faible pour téter, prenait au bol, toutes les deux heures, 10 grammes de lait provenant de la mère les deux premiers jours, puis les jours suivants 30 grammes toutes les 2 h. 30 min.

TABLE 7.—*Indices d'oxygénation.*[1]

Robustes.									Débiles.		
I[2]	II	III	IV	VI	VII	IX	X	XI	V	VIII	XII
1.574	0.742	0.771	0.840	0.718	0.751	0.639	0.745	0.993	0.642	0.637	0.503
1.380	0.940	0.771	1.011	0.742	1.010	0.606	0.836	0.918	0.552	0.562	0.565
1.509	1.051	0.779	0.863	"	0.888	0.937	0.974	1.037	0.584	0.715	0.514
1.841	1.084	0.933	0.856	"	0.932	1.030	1.177	"	0.506	"	0.599
1.465	1.176	1.134	"	"	1.013	"	"	"	"	"	0.657
1.368	1.210	1.051	"	"	"	"	"	"	"	"	"
0.897	1.066	1.189	"	"	"	"	"	"	"	"	"
"	1.210	1.075	"	"	"	"	"	"	"	"	"
"	1.360	"	"	"	"	"	"	"	"	"	"
"	1.311	"	"	"	"	"	"	"	"	"	"

[1]Table II in the Weiss article.
[2]Les nombres de la première colonne (I) ne commencent pas aux premiers jours après la naissance.

It is obvious that the results recently reported from this laboratory on the heat-output of atrophic infants confirm the observations of Weiss, but the existence of abnormalities in the nature of the oxidative processes is hardly essential to explain these differences. The variations in body composition and the variations in cellular and muscular activity fully account for all differences in the amounts of oxygen consumed.

OBSERVATIONS BY BIRK AND EDELSTEIN.

Using the Pettenkofer-Voit respiration apparatus in the Kaiserin Auguste Victoria-Haus in Charlottenburg, Birk and Edelstein[1] in 1910 studied the total carbon-dioxide output of a healthy new-born infant weighing 3,200 grams and 50 cm. long, during the first 3 days of postnatal life. As the authors themselves recognize, the lack of data regarding the oxygen consumption makes it impossible to use the results for discussing the character of the katabolism during the first days of life. The absence of a quantitative measurement of the muscular activity likewise makes it difficult to compare their results with data obtained in researches in which the muscular activity was observed.

OBSERVATIONS BY CARPENTER AND MURLIN.

Employing the differential method, Carpenter and Murlin[2] made observations with the bed respiration calorimeter in the Nutrition Laboratory on pregnant women before and after delivery. By deducting the metabolism of the mother after delivery from that of the mother and child, an attempt was made to estimate the total metabolism of the new-born infant. It is obvious that the difficulties inherent in a differential method of this type make the results of little value for direct comparison with data obtained with new-born infants.

[1]Birk and Edelstein, Monatsschr. f. Kinderheilk., 1910, **9**, p. 505.
[2]Carpenter and Murlin, Archives Internal Med., 1911, **7**, p. 184.

OBSERVATIONS BY BAILEY AND MURLIN.

In an earlier publication of our work, in which we specifically considered the influence of the age of an infant upon the metabolism per square meter of body-surface, we computed the average values for 9 new-born infants ranging in age from 3 hours to 14 days.[1] These results were presented solely for the purpose of discussing the heat production per square meter of body-surface in connection with similar measurements obtained with a large number of atrophic as well as normal infants. Subsequently Bailey and Murlin[2] discussed the energy requirements of new-born infants, chiefly upon the basis of our values, supplemented by their own fragmentary data. It is unnecessary here to enter into a discussion of their results, for in the light of the researches of Hasselbalch, their investigation can hardly be looked upon as more than a substantiation of the earlier research.

PURPOSE AND PLAN OF THE RESEARCH.

The incomplete nature of all of the earlier work with new-born infants and, indeed, of most of the recent studies, the lack of appreciation of the significance of muscular repose during the determination of the total metabolism, and the usually imperfect technique for the measurement of the oxygen consumption, with the consequent liability to error in the estimation of the respiratory quotient, have led us to believe that an extended study of a large number of new-born infants, in which the metabolism during the first week of post-natal life should be definitely established, was not only justifiable, but that the results would be of great significance.

APPARATUS AND TESTS FOR ACCURACY.

The respiration apparatus which was described in our previous reports of studies on infant metabolism[3] and which has been installed at the Massachusetts General Hospital since January 1913, was employed for the measurement of the respiratory exchange of infants during the first week after birth. The tightness of the apparatus was tested each day to demonstrate the absence of any leakage of air which might affect the oxygen measurements. In addition check tests were frequently made in which the respiratory quotient of alcohol was used as an index of accuracy. In consequence we are confident that the apparatus was absolutely tight throughout the whole series of observations.

We wish, however, distinctly to disclaim absolute accuracy for all of the individual respiratory quotients, for with a series of observations including approximately 1,000 periods and extending over 18 months, it is impossible to insure absolute accuracy for the individual

[1]Benedict and Talbot, Am. Journ. Diseases of Children, 1914, **8**, p. 1, tables 13 and 15.
[2]Bailey and Murlin, Am. Journ. Obstetrics, 1915, **71**, p. 526.
[3]Benedict and Talbot, Carnegie Inst. Wash. Pub. 201, 1914, p. 32; also Benedict and Talbot, Am. Journ. Diseases of Children, 1914, **8**, p. 21.

periods of observation. That at times inconceivably low respiratory quotients are found among the data is not surprising. The difficulties of determining accurately the exact temperature of the air in the apparatus, particularly when the infant is restless, needs no special emphasis. Similarly, the equalization of humidity throughout the chamber with no specific ventilation other than that supplied by the air-current likewise presents technical difficulties. The results as a whole are, we believe, accurate and may be accepted without question. It seems fitting, therefore, to present the data exactly as recorded, even though occasionally there may be anomalous differences in the values, rather than to attempt an arbitrary selection which might favor our interpretation of the results. While we have given our data completely, without selection and without reservation, the fact should be emphasized that individual quotients must not be interpreted as significant. It was our purpose to collect such a large mass of results that the general picture of both the character and the amount of the metabolism during the first week of post-natal life would be perfectly defined and clear.

METHOD OF COMPUTATION.

The details of the experimental routine and of the technique may be found in the publication describing our earlier study.[1] As it appears to be difficult for certain writers to understand the method of computing the results obtained in observations of this character, it seems desirable to describe our method of calculation somewhat more fully than has previously been done.

In the determination of the respiratory exchange by an apparatus of the type we employed, it is obvious that the carbon-dioxide output in short periods may be determined more exactly than the oxygen intake. The residual amount of carbon dioxide in the chamber remains constant from period to period, the mechanism supplying the purified air being so adjusted as to replace the air in the chamber some 15 times during a 30-minute period. On the other hand, the determination of the oxygen consumption involves the calculation of the volume of air residual in the chamber at the end of each period. This calculation requires an exact knowledge of the average temperature and the degree of humidity of the air at the end of each period of measurement. As has already been pointed out, the determination of these factors presents great technical difficulties. Since the longer the period of measurement the less the errors influence the results, it has been our custom to measure the carbon dioxide in 30-minute periods, with, so far as possible, complete muscular repose on the part of the infant, and to calculate the oxygen intake only once for the entire time that the child remains in the respiration chamber. It may reasonably be assumed that differences in the muscular activity, especially with the

[1]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 31.

new-born infant, will not cause a marked difference in the character of the katabolism so that when a comparison is made of the carbon-dioxide production and the oxygen consumption for the entire period of observation, *i. e.*, $1\frac{1}{2}$ to 2 hours, the result may be fairly considered as representing the average respiratory quotient for that period. If in this time there is a 30-minute period of complete muscular repose during which the carbon-dioxide output has been measured, the heat-output may be computed for this minimum period by the method of indirect calorimetry, *i. e.*, by multiplying the carbon-dioxide production for the 30-minute period by the calorific equivalent of carbon dioxide for the respiratory quotient prevailing during the entire period of $1\frac{1}{2}$ to 2 hours.

The heat output for the entire period of observation may be obtained not only by using the carbon-dioxide production for that period, but may also be secured by multiplying the oxygen consumption by the calorific equivalent of oxygen for the respiratory quotient during the period of observation. In view of the technical difficulties of measuring the oxygen consumption, however, this factor may not properly be used for calculating the heat-output for the minimum period.[1]

It may be argued that the assumption of a representative respiratory quotient for the entire period of observation for use in computing the heat-output during the minimum period may lead to error, since there may be a slight, normal fall in the respiratory quotient (particularly if the observation is preceded by nursing), this fall being due to the fact that the carbohydrate of milk probably burns more rapidly than the fat and the protein. It is fair to assume, however, that the error caused by the use of this average respiratory quotient in the formula for indirectly computing the heat-output from the carbon-dioxide production for a 30-minute period is certainly no greater and is probably less than that involved in the direct measurement of the oxygen consumption with its attendant temperature and barometric measurements at the beginning and end of the period. In our research we desired not only to determine the character of the katabolism, but also, if possible, to determine the minimum basal metabolism. Since this was usually determinable only in 30-minute periods, the method of computation just outlined was applied to these experiments.

[1]It should be said that the proper thermometer, barometer, psychrometer, spirometer, and meter readings were recorded at the end of every period. Calculations based upon these showed for the most part good agreement in each period between the heat indirectly calculated from the carbon-dioxide output and the average respiratory quotient and that calculated from the oxygen consumption and the average respiratory quotient. This fact has been cited in discussing the maximum heat-output (see table 18, p. 113). Nevertheless, as each absolute value for the oxygen determination may possibly be subject to the errors previously cited, the values for the heat-output in this publication, except in table 18, have been calculated from the carbon-dioxide determinations, using the calorific value of carbon dioxide corresponding to the average respiratory quotient for the entire sojourn inside the chamber.

CARE OF THE NEW-BORN INFANT.

The general routine followed at the Boston Lying-In Hospital for the care of infants during and after delivery is as follows:

The infant is delivered in the "case room" of the hospital. This room is kept at a temperature of 80° to 84° F. Ordinarily, after the baby is delivered, it is held up by the feet in order to drain the mucus from its mouth and throat. About one out of five babies is patted on the back to make it cry and in this way to expand the lungs. The cord is then cut, tied with two ligatures, and sterile dressings applied. These dressings consist of two sterile sponges, one of which is put around the cord and the other over the cord. The dressings are held in place by a gauze band placed over them. The infant is laid in a crib on its right side, with a blanket so folded about it as to cover the entire body, and with the feet slightly elevated, so that the mucus may continue to drain from the mouth. A tin heater, with a temperature of about 100° F. and covered with Canton flannel, is then put at the baby's back at such distance that a hand can be placed between the heater and the body of the infant. The baby is left in the crib for $1\frac{1}{2}$ to 2 hours after birth, while the nurse is caring for the mother. As soon as the nurse is free, the baby is bathed in cotton-seed oil. The temperature of the oil is not known, but the nurse says that it is "kept warm" and is probably the same temperature as that of the room (80° to 84° F.) or a little warmer. After the oil-bath, the infant is powdered with castile soap and washed in sterile water, the temperature of the bath being about 100° F. The exposure to the air is in all about 15 minutes, this including the oiling, bathing, and weighing.

The infant is next taken to the "ward room," which has a temperature of 68° to 74° F., and put in its crib, where it remains until it is nursed. It is first put to the breast 8 hours after birth and subsequently every 6 hours during the first 24 hours, the nursing period being 3 to 4 minutes. Some babies take hold of the nipple and nurse immediately, while others are lazy and have to be urged by the attendant. During the second day the baby is put to the breast every 4 hours and is left there 3 to 4 minutes. In the third 24 hours, the baby is nursed every 2 hours during the day and every 4 hours during the night, thus making, in all, 10 feedings. When the milk secretion is once established, *i. e.*, when "the milk comes in," the baby is left at the breast 10 minutes at each feeding.

This routine was varied somewhat when the infants were taken to the respiration apparatus within an hour of birth. An extra nurse took the baby after delivery and oiled, bathed, and dressed it as previously described. It was then wrapped in two or three blankets, the number varying with the weather. The blankets were drawn up so as to form a hood almost entirely covering the infant's head and the baby was then carried in the nurse's arms from the Lying-In Hospital to

the Massachusetts General Hospital. The distance between the front doors of these two hospitals is 177 paces and not more than 2 or 3 minutes are required to go from one building to the other. On reaching the observation room, the baby was placed in the respiration chamber. When the measurements of the respiratory exchange were completed, the baby was weighed and measured and then returned immediately to the Lying-In Hospital.

The routine followed for one infant which was studied shortly after birth is shown by the notes given below and is fairly typical of the routine used for the infants studied under these circumstances.

Baby R. (No. 94), negro.—Born at $2^h\ 12^m$ p. m., April 28, 1915. Low forceps case. Message received at the observation room at $2^h\ 20^m$ p. m. Baby received in the case room at $2^h\ 27^m$ p. m. It had been exposed at birth 3 to 4 minutes. This exposure was less than usual, as the mother had a hemorrhage and required immediate attention. The cord was therefore simply clamped. Usually the baby lies in the physician's lap 6 to 8 minutes before the cord is cut. The infant was also exposed about 5 minutes shortly after birth while it was being immersed in water of a temperature of 100° to 105° F., and wrapped in warm blankets with heaters. At $2^h\ 30^m$ p. m. it was exposed for 3 or 4 minutes when the cord was ligated and cut. The infant was then weighed, oiled, and the length measured, this requiring 5 minutes. The cord was dressed, the band applied, and the baby dressed in the period of 5 minutes. A bonnet and small coat were put on the infant, which was also wrapped in two large blankets. The nurse and baby left the Lying-In Hospital about $2^h\ 55^m$ p. m. and arrived in the observation room in the Massachusetts General Hospital at 3 p. m., where a study was made of the respiratory exchange.

STATISTICS OF THE OBSERVATIONS.

The clinical statistics of the 105 infants studied in this research are given in table 8, with full data regarding birth.

The results of the observations on the gaseous exchange of the same infants are given in chronological order in table 9. The infants included in this research are referred to throughout by numbers, but in the first column of this table the initials have also been given for such of the infants as were included in the previous report.[1] The sex and the dates of the individual observations are given in the next two columns. The length of the infant in centimeters, also the age and weight for each observation, are given in succeeding columns, and the actual length of each period from which the per hour figures are calculated is given under "Duration of period." The data for the preliminary periods, *i. e.*, the carbon dioxide produced per hour and the pulse-rate, are shown by the first values given for each observation. These values were not used in calculating the respiratory quotient for the whole observation, only those in brackets (if more than one period was used) being included in this calculation. The heat-production per 24 hours is given on the three bases of total heat-production and heat-production per kilogram of body-weight and per square meter of body-surface. The pulse-rate is an average value for the several counts made during each period. The data for the rectal temperature represent the records made at the beginning and end of the observations. Prior to November 1914 the body-temperature was recorded about 30 minutes before the measurement of the metabolism began. After November 1914 the record was made approximately 3 minutes before the beginning of the preliminary period of observation; this was always the routine with the very young infants in the later observations. Temperature records were usually taken within 5 minutes after the end of the observation and always within 10 minutes. The data regarding the feeding show the time between the taking of food and the beginning of the metabolism measurements, also the kind and composition of the food. Nearly all of the infants were normal, but a few were pathological cases, these being indicated in the notes accompanying the table.

[1]Benedict and Talbot, Am. Journ. Diseases of Children, 1914, 8, p. 1, tables 13 and 15.

TABLE 8.—*Clinical statistics of infants.*

Subject No.	Sex.	Date of birth.	Birth.	Term.	Delivery.	Birth-weight.			Length.
						lbs.	*oz.*	*kilos.*	*cm.*
1	M.	1913 Dec. 3	Primiparous...	Full term...	Cæsarian section.	[1]6	14½	[1]3.13	52
		1914							
2	F.	Jan. 8	Multiparous..	.....do.....	Normal.....	[2]8	5½	[2]3.79	53
3	M.	Mar. 16	Primiparous...	.....do.....	.....do.....	8	14	4.03	52
4	F.	Mar. 22	Multiparous..	.....do.....	.....do.....	7	15	3.60	46.5
5	M.	Mar. 30	.....do.....	.....do.....	Low forceps...	8	6½	3.81	52.5
6	M.	Mar. 31	.....do.....	.....do.....	Normal.....	10	2	4.59	52
7	M.	...do....	Primiparous...	.....do[3]....	.....do.....	8	..	3.63	51.5
8	M.	Apr. 6	Multiparous..	.....do.....	.....do.....	8	..	3.63	51
9	F.	Apr. 9	.....do.....	.....do.....	.....do.....	9	11½	4.41	51
10	M.	Apr. 11	Primiparous...	.....do.....	.....do.....	8	..	3.63	52
11	M.	Apr. 15	Multiparous..	.....do.....	.....do.....	8	15½	4.07	52
12	F.	Apr. 18	.....do.....	.....do.....	.....do.....	8	11½	3.95	52.5
13	F.	Apr. 21	Primiparous...	.....do.....	.....do.....	[4]7	7	[4]3.37	50
14	M.	Apr. 27	Multiparous..	.....do.....	.....do.....	9	5	4.22	51
15	M.	May 3	Primiparous...	.....do.....	.....do.....	8	5	3.77	50
16	F.	May 5	Multiparous..	.....do.....	.....do.....	9	1	4.11	53
17	F.	May 11	.....do.....	.....do.....	.....do.....	8	1½	3.67	52.5
18	M.	...do....	.....do.....	.....do.....	.....do.....	7	..	3.18	50.5
19	M.	May 17	.....do.....	.....do.....	.....do.....	7	14	3.57	53
20	F.	May 24	.....do.....	.....do.....	.....do.....	8	8	3.86	52
21	F.	...do....	.....do.....	.....do.....	.....do.....	6	15	3.15	50
22	F.	May 31	.....do.....	.....do.....	.....do.....	6	5	2.86	49
23	F.	...do....	Primiparous...	.....do.....	.....do.....	8	2	3.69	50.5
24	M.	June 7	.....do.....	Premature[5].	.....do.....	5	3	2.35	43
25	M.	...do....	.....do.....	Full term...	.....do.....	7	8	3.40	51.5
26	F.	June 6	Multiparous..	.....do.....	.....do.....	8	..	3.63	50
27	M.	June 15	.....do.....	.....do.....	.....do.....	8	8	3.86	52
28	F.	June 17	.....do.....	.....do.....	.....do.....	8	3½	3.73	50.5
29	F.	June 24	.....do.....	.....do.....	.....do.....	8	..	3.63	50
30	M.	...do....	Primiparous...	.....do.....	.....do.....	7	14	3.57	51
31	M.	Oct. 15	Multiparous..	.....do.....	.....do.....	8	2½	3.70	53.5
32	M.	Oct. 19	Primiparous...	.....do.....	Low forceps...	7	15	3.60	47.5
33	M.	Oct. 23	Multiparous..	.....do.....	Normal.....	9	1	4.11	52
34	F.	Oct. 24	.....do.....	.....do.....	.....do.....	7	3	3.26	50.5
35	F.	Oct. 29	.....do.....	.....do.....	Cæsarian section.	10	10	4.82	54
36	M.	Nov. 1	Primiparous...	.....do.....	Low forceps...	7	12	3.52	53
37	F.	Nov. 3	.....do.....	.....do?....	Normal.....	5	8	2.49	46.5
38	F.	Nov. 9	Multiparous..	.....do.....	.....do.....	9	4	4.20	51.5
39	F.	...do....	.....do.....	.....do.....	.....do.....	6	8	2.95	50
40	F.	Nov. 11	.....do.....	.....do?.....	.....do.....	6	7	2.92	49.5
41	M.	Nov. 16	.....do.....	.....do[6]....	.....do.....	8	10	3.91	51.5
42	F.	...do....	Primiparous...	.....do.....	.....do.....	9	6	4.25	54
43	F.	...do....	Multiparous..	.....do.....	.....do.....	8	11	3.94	50
44	F.	Nov. 19	.....do.....	.....do[7].....	.....do.....	7	14	3.57	51
45	F.	Nov. 22	Primiparous...	.....do?....	.....do.....	5	14	2.66	46.5
46	M.	Nov. 27	.....do.....	.....do.....	Low forceps...	8	7	3.83	51.5
47	M.	Nov. 30	Multiparous..	.....do.....	Normal.....	8	15	4.05	52
48	F.	Dec. 6	.....do.....	.....do.....	Low forceps...	10	10	4.82	54.5
49	F.	Dec. 8	.....do.....	.....do.....	Normal.....	6	7	2.92	47.5
50	F.	Dec. 13	.....do.....	.....do.....	.....do.....	6	13	3.09	48.5
51	M.	Dec. 14	.....do.....	.....do.....	.....do.....	8	14	4.03	52.5

[1]Not birth-weight but weight obtained on the third day.
[2]Weight obtained after 6 days.
[3]Toxemia of pregnancy.
[4]Weight obtained after 25 hours.
[5]Between 7 and 8 months.
[6]Congenital heart.
[7]Syphilis.

TABLE 8—*Clinical statistics of infants*—Continued.

Subject No.	Sex.	Date of birth.	Birth.	Term.	Delivery.	Birth-weight.			Length.
						lbs.	*oz.*	*kilos.*	*cm.*
		1914.							
52	F.	Dec. 20	Multiparous..	Full term...	Normal	8	2	3.69	50
53	M.	Dec. 27	Primiparous...	.....do.....	.....do.....	7	1½	3.22	47.5
54	M.	Dec. 30	.....do.....	.....do.....	.....do.....	[1]7	7	[1]3.38	50
		1915							
55	M.	Jan. 3	Multiparous..	.....do.....	.....do.....	8	5	3.77	50
56	M.	Jan. 2	Primiparous...	.....do.....	.....do.....	7	6½	3.36	51.5
57	M.	Jan. 7	Multiparous..	.....do.....	.....do.....	8	13	4.00	54
58	F.	Jan. 11	Primiparous...	.....do.....	.....do.....	7	..	3.18	49
59	F.	Jan. 14	Multiparous..	.....do.....	.....do.....	8	14	4.03	52
[2]60	M.	Jan. 13	.....do.....	.....do.....	.....do.....	9	2	4.14	52
61	M.	Jan. 20	Primiparous...	.....do.....	.....do.....	7	3	3.26	49.5
62	M.	Jan. 25	.....do.....	.....do.....	.....do.....	7	11	3.49	49.5
63	F.	Feb. 2	Multiparous..	.....do.....	.....do.....	6	3	2.81	47.5
64	F.	Feb. 4	.....do.....	.....do.....	.....do.....	7	7	3.37	48
65	F.	Feb. 7	Primiparous...	.....do.....	.....do.....	5	14	2.66	49
66	M.	Feb. 9	.....do.....	.....do.....	.....do.....	7	6	3.35	51
67	M.	Feb. 12	Multiparous..	.....do.....	.....do.....	11	..	4.99	54
68	M.	Feb. 15	Primiparous...	.....do.....	Low forceps...	5	7½	2.48	46
69	M.	Feb. 17	Multiparous..	.....do.....	Normal.....	8	2	3.69	50
70	M.	Feb. 22	Primiparous...	.....do.....	.....do.....	8	10½	3.93	51
71	M.	Feb. 21	.....do.....	.....do.....	.....do.....	9	2	4.14	53.5
72	M.	Feb. 26	Multiparous..	.....do.....	Cæsarian section.	7	11	3.49	50.5
73	M.	Mar. 3	Primiparous...	.....do.....	Normal.....	8	..	3.63	50
74	M.	Mar. 7	.....do.....	.....do[3]	.....do.....	8	7	3.83	52
75	M.	...do....	Multiparous..	.....do.....	.....do.....	6	6	2.89	47.5
76	M.	Mar. 10	.....do.....	.....do.....	.....do.....	7	2	3.23	50
77	F.	Mar. 12	Primiparous...	.....do.....	.....do?.....	8	10	3.91	53
78	M.	Mar. 15	Multiparous..	.....do.....	.....do.....	5	7½	[4]2.48	47
79	F.	Mar. 16	.....do.....	.....do.....	.....do.....	9	2	4.14	52.5
80	M.	Mar. 19	Primiparous...	.....do.....	.....do.....	7	10½	3.47	51.5
81	F.	Mar. 22	Multiparous..	.....do.....	.....do.....	7	4	3.29	50
82	M.	Mar. 23	Primiparous...	.....do.....	.....do.....	6	½	2.74	49
83	M.	Mar. 24	.....do.....	.....do.....	.....do.....	8	3½	3.73	52
84	F.	Mar. 26	Multiparous..	.....do.....	.....do.....	9	1	4.11	54
85	M.	...do....	.....do.....	.....do.....	.....do.....	7	14	3.57	52
86	F.	Mar. 30	.....do.....	.....do.....	.....do.....	7	5	3.32	51
87	M.	Mar. 31	.....do.....	.....do.....	.....do.....	8	11	3.94	51
88	F.	Apr. 2	Primiparous...	.....do.....	Low forceps...	5	13	2.64	47.5
89	M.	Apr. 20	Multiparous..	.....do.....	Normal.....	7	3	3.26	49.5
90	M.	Apr. 19	Primiparous...	.....do.....	.....do.....	7	6	3.35	50
91	F.	Apr. 22	Multiparous..	.....do.....	.....do.....	7	5½	3.33	49.5
92	F.	Apr. 24	.....do.....	.....do.....	.....do.....	8	5½	3.78	51
93	M.	Apr. 27	.....do.....	.....do.....	Low forceps...	7	12½	3.53	50.5
[2]94	M.	Apr. 28	Primiparous...	.....do.....	.....do.....	7	1	3.20	50
95	F.	May 1	Multiparous..	.....do.....	Normal.....	6	4	2.84	46.5
96	F.	May 3	Primiparous...	.....do.....	Low forceps...	7	8	3.40	51.5
97	F.	May 6	.....do.....	.....do.....	.....do.....	6	7½	2.93	48
98	F.	May 7	.....do.....	.....do.....	Normal.....	6	5	2.86	47.5
99	M.	May 11	Multiparous..	.....do.....	.....do.....	8	3	3.71	51.5
100	M.	May 13	.....do.....	.....do.....	.....do.....	10	4	4.65	54
101	M.	May 17	.....do.....	.....do.....	.....do.....	8	9	3.88	51.5
102	M.	May 19	Primiparous...	.....do.....	.....do.....	6	3½	2.82	47.5
103	F.	May 21	Multiparous..	.....do.....	.....do.....	7	4	3.29	49
104	M.	May 24	Primiparous...	.....do.....	.....do.....	7	5	3.32	51
105	M.	May 26	Multiparous..	.....do.....	.....do.....	7	6	3.35	50.5

[1]Weight obtained after 6½ hours.
[2]Negro.
[3]Postpartum eclampsia.
[4]Weight obtained after 11 hours.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants.*

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{w^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1913				$18\frac{1}{4}$	2.33	....	...	...	....	115				
[3]1	M.	Dec. 6	52	2 12	3.13	45	1.85		151	48	683	112				
						30	1.90	.65	155	50	701	110	37.0	37.0	1 ..	Breast-milk.
						40	1.95		159	51	719	114				
						$21\frac{1}{4}$	2.20	....	...	...	....	119				
		Dec. 8	....	4 12	2.90	46	1.76		144	50	686	114				
						40	1.74	.63	142	49	676	116	38.3	38.0	1 ..	Do.
						40	2.07		169	58	805	120				
						$19\frac{1}{2}$	2.34	....	...	...	....	107				
		Dec. 11	....	7 12	2.73	50	2.09		171	63	847	115				
						45	1.85	.65	151	55	748	113	37.8	38.1	1 ..	Do
						35	2.31		189	69	936	115				
		1914														
2	F.	Jan. 14	53	6 ..	3.79	18	2.13	....	...	...	....	95				
						41	1.90	.69	155	41	618	103	37.1	37.0	.. 30	Formula: fat, 2 p. ct.; lactose, 5 p. ct.; protein, 0.5 p. ct.; $1\frac{1}{4}$ oz. at feeding.
						44	2.13		174	46	693	103				
		Jan. 15	....	7 ..	3.80	$30\frac{1}{2}$	2.38	....	...	...	....	107				
						32	1.82	.70	149	39	594	95	[4]36.6	[4]36.4	1 ..	Same as on Jan. 14.
						39	2.17		177	47	705	101				
[5]3 (I. N.)	M.	Mar. 18	52	1 21	3.61	12	2.50	....	...	...	....	84				
						41	2.05	.69	168	47	694	95	36.9	37.0	3 ..	Partly colostrum.
		Mar. 19	....	3 ..	3.64	$13\frac{1}{2}$	2.89	....	...	...	....	104				
						29	2.01	.70	164	45	675	99	37.0	37.1	.. 30	Colostrum and breast-milk.
						31	2.17		177	49	728	105				
		Mar. 20	....	4 ..	3.69	$17\frac{1}{2}$	2.74	....	...	...	....	108				
						30	2.22	.68	182	49	740	109	36.7	36.7	1 ..	Do.
						31	2.21		181	49	736	114				
		Mar. 21	....	5 ..	3.71	$21\frac{1}{2}$	4.33	....	...	...	....	135				
						34	3.95	.84	279	75	1,130	119	36.7	37.2	1 ..	Breast-milk.

[5]4 (R. D.)	F.	Mar. 23	46.5	..	16	3.52	20	2.37	....	...	...	....	128	37.1	37.6	..	..	No food; sterile water given.
							46	2.45	.86	170	48	714	126					
		Mar. 24	....	1	16	3.28	13	2.68	....	...	...	....	97	37.3	37.3	..	30	Colostrum.
							33	1.76	.70	144	44	634	101					
							36	2.05		168	51	740	101					
		Mar. 25	....	2	12	3.27	26	2.75	....	...	...	....	115	37.1	37.0	1	..	Colostrum; sterile water 4 minutes before the observation.
							31	1.80	.75	139	43	612	108					
							32	1.73		134	41	590	107					
		Mar. 26	....	3	12	3.26	20	2.46	....	...	...	....	132	37.8	37.3	1	..	Colostrum; breast-milk commencing.
							34	1.87	.68	153	47	677	119					
							32	1.84		150	46	664	119					
		Mar. 27	....	4	12	3.41	18½	2.69	....	...	...	....	106	36.5	36.4	..	30	More breast-milk.
							34	2.31	.89	156	46	670	105					
							33	2.13		144	42	618	103					
		Mar. 28	....	5	12	3.40	13½	3.02	....	...	...	....	113	36.9	36.7	1	..	Breast-milk.
							34	2.31	.80	169	50	725	115					
							35	2.40		176	52	755	112					
[5]5 [5](T. K.)	M.	Mar. 30	52.5	..	7	3.82	18½	3.37	....	...	...	....	128	37.2	36.6	..	..	Sterile water 2 minutes before the observation.
							35	2.31	.82	166	43	659	114					
							37	1.90		137	36	544	112					
		Mar. 31	....	1	7	3.38	31½	2.90	....	...	...	....	113	37.4	36.7	7	..	Partly colostrum; sterile water 1 hour before the observation.
							33	2.11	.71	170	50	733	110					
							35	2.06		166	49	716	103					
[5]6 (F. R.)	M.	Mar. 31	52	..	6	4.60	26	4.15	....	...	...	....	127	37.2	37.0	..	..	No food; sterile water given.
							38	3.43	.90	229	50	804	127					
							36	2.82		188	41	660	123					
		Apr. 1	....	1	1½	4.36	15	3.20	....	...	...	....	112	37.0	37.4	3	..	Colostrum; sterile water 5 minutes before the observation.
							34	2.88	.69	236	54	858	124					
							34	2.89		236	54	858	128					
		Apr. 2	....	2	..	4.23	21	2.49	....	...	...	....	132	37.0	38.3	..	30	Colostrum; sterile water 9 minutes before the observation.
							34	2.54	.72	203	48	755	136					
							29	4.78		381	90	1416	160					
		Apr. 3	....	3	..	4.25	23½	3.24	....	...	...	....	131	37.0	37.0	..	30	Breast-milk; sterile water 2 minutes before the observation.
							32	2.42	.69	198	47	733	121					
							34	2.65		217	51	804	113					
		Apr. 4	....	4	..	4.38	17½	3.53	....	...	...	....	119	37.0	36.9	1	..	Breast-milk.
							36	2.67	.82	192	44	696	116					
							33	2.55		183	42	663	111					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old, the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]Died subsequently of congenital syphilis and jaundice.

[4]Axillary temperature.

[5]Results with this subject have been previously published. (See Benedict and Talbot, Am. Journ. Diseases of Children, 1914, 8, pp. 38–39.)

[6]Intracranial hemorrhage found at operation on April 12, 1914.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1914.				$18\frac{1}{2}$	4.44	....	...	...	....	133				
37 (I. R.)	M.	Apr. 6	51.5	6 ..	3.90	37	3.24	0.84	229	59	898	130	36.7	37.0	1 ..	Breast-milk.
						35	3.96		279	72	1,094	138				
						31	3.02		213	55	835	128				
						$38\frac{1}{2}$	4.39	....	...	...	....	132				
		Apr. 7	....	7 ..	3.89	32	3.19	.87	219	56	859	127	36.7	37.2	1 ..	Do.
						29	3.08		211	54	827	126				
						$21\frac{1}{2}$	2.85	....	...	...	....	105				
38 (O. C.)	M.	Apr. 6	51	.. 5	3.64	33	2.22	.77	168	46	691	112	37.0	36.7	.. ..	No food; sterile water 3 minutes before the observation.
						42	2.00		151	41	621	109				
						16	3.34	....	...	...	....	148				
		Apr. 7	....	1 5	3.37	31	2.98	.76	228	68	983	148	37.2	37.8	5 ..	Colostrum; sterile water 2 minutes before the observation.
						34	3.49		267	79	1,151	162				
						20	2.70	....	...	...	....	132				
		Apr. 8	....	2 ..	3.40	32	2.18	.63	178	52	764	141	37.0	37.0	.. 30	Colostrum; breast-milk commencing.
						32	2.10		172	51	738	147				
						$19\frac{1}{2}$	3.26	....	...	...	....	137				
		Apr. 9	....	3 ..	3.31	31	2.23	.72	178	54	777	136	36.9	36.7	1 ..	Breast-milk.
						31	2.03		162	49	707	129				
						12	3.15	....	...	...	....	103				
39 (R. C.)	F.	Apr. 10	51	1 $1\frac{1}{2}$	4.21	30	2.50	.75	193	46	717	103	36.7	37.0	3 ..	Colostrum.
						32	2.48		191	45	710	109				
						19	2.59	....	...	...	....	98				
		Apr. 11	....	2 ..	4.04	30	2.42	.77	183	45	698	107	37.2	37.4	1 ..	Breast-milk commencing.
						30	2.28		172	43	656	111				
						19	2.78	....	...	...	....	101				
10	M.	Apr. 13	52	1 11	3.52	30	2.26	.67	185	53	777	114	36.7	36.7	3 ..	Colostrum; sterile water 3 minutes before the observation.
						30	2.00		164	47	689	113				

		Apr. 14	....	2	12	3.37	19	2.12	....	...	...	....	104	36.7	37.0	..	30	Breasts filled; sterile water 2 minutes before the observation.
							30	2.00	.65	164	49	707	119						
							31	1.94		159	47	685	115						
[3]11 (U. H.)	M.	Apr. 15	52	..	3	4.08	16	3.45	....	...	...	....	103	36.7	37.0	..	..	No food.
							30	2.62	.86	181	44	688	101						
							32	2.21		153	38	582	105						
		Apr. 16	....	1	3	3.92	37½	2.58	....	...	...	....	124	37.2	37.3	5	..	Colostrum.
							31	2.50	.72	200	51	781	127						
							31	2.25		180	46	703	123						
		Apr. 17	....	2	..	3.77	23	2.61	....	...	...	....	117	36.9	36.9	..	30	Breast-milk.
							30	2.50	.66	204	54	816	113						
							33	2.22		182	48	728	107						
		Apr. 21	....	6	..	4.00	19	4.20	....	...	...	....	132	36.9	37.0	..	30	Do.
							32	2.74	.83	195	49	750	125						
							33	3.27		233	58	896	119						
12	F.	Apr. 22	52.5	4	..	4.17	30	3.02	....	...	...	....	118	36.9	37.0	1	..	Breast-milk.
							30	2.62	.75	202	48	757	110						
							30	2.14		165	40	618	104						
		Apr. 23	....	5	..	4.11	17	2.61	....	...	...	....	123	37.2	37.2	..	30	Do.
							31	2.34	.73	185	45	701	118						
							32	2.33		184	45	697	116						
		Apr. 24	....	6	..	4.17	22½	3.33	....	...	...	....	130	37.2	36.9	..	30	Do.
							33	2.44	.78	183	44	685	119						
							34	2.35		176	42	659	120						
		Apr. 25	....	7	..	4.17	18	2.80	....	...	...	....	141	37.2	37.0	..	30	Do.
							35	2.67	....	[4]206	49	772	136						
							32	2.27	....	[4]175	42	655	128						
13	F.	Apr. 22	50	1	1	3.37	19	3.19	....	...	...	....	120	36.7	36.9	4	..	Colostrum.
							32	1.93	.83	137	41	591	113						
							44	3.63		258	77	1,112	121						
							30	3.14		224	66	966	114						
		Apr. 23	....	2	..	3.20	21	2.14	....	...	...	....	121	36.9	37.2	1	30	Do.
							40	3.90	.77	295	92	1,317	128						
							33	1.89		143	45	638	111						
							36	1.83		138	43	616	114						
		Apr. 24	....	3	..	3.19	17½	2.23	....	...	...	....	115	37.3	37.2	1	..	Breasts filling.
							30	2.06	.84	145	45	647	112						
							30	1.92		135	42	603	113						
							31	4.99		352	110	1,571	135						

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]Results with this subject have been previously published. (See Benedict and Talbot, Am. Journ. Diseases of Children, 1914, **8**, pp. 38–39).

[4]The average of the respiratory quotients obtained in the three preceding days has been used in computing the heat values on this day.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1914.				$15\frac{1}{2}$	2.67	....	...	...	....	119				
14	M.	Apr. 27	51	.. 9	4.22	31	2.54		188	45	699	114	36.9	36.7	.. ..	No food.
						36	2.23	0.79	165	39	613	122				
						31	2.48		184	44	684	118				
						$16\frac{1}{2}$	2.47	....	...	...	....	106				
		Apr. 28	....	1 9	3.95	35	2.64		208	53	806	104	37.6	37.1	3 30	Colostrum.
						34	2.22	.73	175	44	678	110				
						34	2.49		196	50	760	106				
						24	3.73	....	...	...	....	114				
		Apr. 29	....	2 12	3.80	39	4.51		348	92	1,386	132	37.6	38.4	1 30	Do.
						30	5.32	.75	411	108	1,637	138				
						32	4.93		381	100	1,518	136				
						$14\frac{1}{2}$	2.69	....	...	...	....	113				
						32	2.31		178	48	721	111				Formula: fat, 2 p. ct.; lactose, 5 p. ct.; protein, 0.8 p. ct.; $1\frac{1}{2}$ oz. at feeding.
		Apr. 30	....	3 12	3.71	33	2.18	.75	168	45	680	115	36.9	36.8	.. 30	
						30	2.22		171	46	692	111				
						27	2.00		154	42	623	114				
						42	3.36	....	...	...	....	118				
		May 1	....	4 12	3.77	33	2.51	.80	184	49	736	109	36.7	37.1	.. 30	Same as on Apr. 30.
						42	5.30		389	103	1,556	128				
						$15\frac{1}{2}$	2.86	....	...	...	....	127				
15	M.	May 4	50	.. 11	3.77	31	2.57	.80	188	50	752	122	36.7	36.2	.. ..	No food.
						35	2.26		166	44	664	120				
						19	2.34	....	...	...	....	122				
		May 5	....	1 11	3.74	30	2.26	.69	185	49	746	121	37.6	36.9	2 30	Colostrum.
						31	2.63		215	57	867	125				
						$20\frac{1}{2}$	3.45	....	...	...	....	136				
		May 6	....	2 12	3.73	32	2.06	.68	168	45	677	125	37.2	36.9	.. 30	Breasts filling.
						32	2.33		191	51	770	124				

		May 7	....	3	12	3.67	18	2.77	....	...	...	....	122	36.7	36.6	..	30	Breast-milk.
							33	2.35	.72	188	51	767	119					
							32	2.48		198	54	808	122					
		May 8	....	4	12	3.63	19	3.66	....	...	...	....	138	36.7	37.2	..	30	Do.
							29	3.43	.75	265	73	1,091	137					
							36	2.03		157	43	646	121					
		May 9	....	5	12	3.57	18	2.23	....	...	...	....	120	37.3	36.7	..	30	Do.
							31	2.15	.73	170	48	708	120					
							35	2.04		161	45	671	119					
		May 11	....	7	12	3.80	16	2.70	....	...	...	....	123	36.7	36.9	..	30	Do.
							27	2.42	.94	157	41	625	121					
							33	4.42		286	75	1,139	131					
							17	2.65	....	...	...	....	124					
							31	2.38		182	44	689	115					
16	F.	May 6	53	..	16	4.11	30	2.80	.76	214	52	811	124	37.0	37.2	1	30	Colostrum.
							26	2.47		189	46	716	112					
							30	2.68		205	50	777	121					
							40	3.54	....	...	...	....	125					
		May 7	....	1	16	4.08	30	2.16		165	40	627	110	36.9	37.2	1	..	Do.
							30	2.66	.76	203	50	772	120					
							30	2.58		197	48	749	115					
							$22\frac{1}{2}$	3.20	....	...	...	....	119					
		May 8	....	2	12	3.91	30	2.36		182	47	711	107	37.0	37.0	1	..	Do.
							30	2.70	.75	208	53	813	111					
							45	2.60		201	51	785	109					
							$53\frac{1}{2}$	3.80	....	...	...	....	126					
		May 9	....	3	12	3.97	31	2.69	.88	183	46	707	112	37.0	37.2	1	..	Breasts filling.
							30	4.52		308	78	1,189	132					
							$18\frac{1}{2}$	3.73	....	...	...	....	135					
		May 11	....	5	12	4.00	25	2.54		170	43	654	121	37.0	37.4	1	30	Breast-milk.
							43	4.67	.90	312	78	1,200	139					
							30	4.20		281	70	1,081	139					
							$22\frac{1}{2}$	2.21	....	...	...	....	115					
17	F.	May 12	52.5	..	15	3.66	31	2.48	.76	189	52	775	118	36.3	37.3	3	30	Colostrum.
							36	2.25		172	47	705	116					
							36	2.30		176	48	721	119					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
						17	3.64	....	...	...	....	133				
		1914.				32	2.87		222	65	949	122				
17 (Cont.)	F.	May 13	....	1 15	3.43	30	3.20	0.75	247	72	1,056	126	36.9	37.9	3 30	Colostrum.
						28	4.18		323	94	1,380	126				
						37	3.34		258	75	1,103	125				
						26½	2.42	....	...	...	....	137				
						30	2.38		190	56	815	130				
		May 14	....	2 12	3.40	30	2.52	.72	201	59	863	121	37.6	37.2	.. 30	Breast-milk commencing.
						31	2.32		185	54	794	122				
						36½	3.57	....	...	...	....	135				
						34	2.21		174	51	747	123				
		May 15	....	3 12	3.40	31	2.32	.73	183	54	785	122	36.9	36.7	1 ..	Breast-milk.
						31	2.21		174	51	747	119				
						17	2.75	....	...	...	....	110				
18	M.	May 12	50.5	.. 18½	3.18	32	2.51	.81	182	57	816	119	37.0	36.9	.. ..	No food.
						33	2.22		161	51	722	115				
						21½	2.12	....	...	...	....	103				
		May 13	....	1 18½	3.03	35	1.92	.65	157	52	727	105	37.0	36.8	2 30	Colostrum.
						33	1.84		150	50	694	108				
						18½	2.08	....	...	...	....	102				Breast-milk; also formula: fat, 2 p. ct.; lactose, 5 p. ct.; protein, 0.75 p. ct.; ½ oz. at feeding.
		May 14	....	3 ..	2.91	32	1.74	.60	142	49	676	101	37.2	36.8	.. 30	
						38	1.72		141	48	671	107				
						15	1.88	....	...	...	....	121				
		May 15	....	4 ..	2.92	36	1.68	.67	137	47	649	115	36.7	37.0	.. 30	Breast-milk.
						33	2.16		177	61	839	113				
						23½	1.79	....	...	...	....	106				
		May 16	....	5 ..	2.86	35	2.01	.72	160	56	769	115	37.0	36.4	.. 30	Do.
						34	1.68		134	47	644	109				

							$14\frac{1}{2}$	1.90	....	...	...	....	104					
							41	1.39		104	37	502	101					
		May 18	....	7	..	2.84	42	1.49	.78	111	39	536	108	36.9	36.3	1	..	Do.
							36	1.68		126	44	609	108					
							$21\frac{1}{2}$	2.71	....	...	...	....	123					
19	M.	May 18	53	..	21	3.47	31	2.69	.82	193	56	818	122	37.1	37.0	..	..	No food; would not take sterile water about 1 hour before the observation.
							30	2.16		155	45	657	116					
							21	2.06	....	...	...	....	108					
		May 19	....	1	21	3.52	33	2.20	.84	155	44	651	112	36.7	36.9	..	30	Colostrum.
							41	2.20		155	44	651	115					
							$17\frac{1}{2}$	2.09	....	...	...	....	91					
		May 21	....	4	..	3.37	32	2.34	.86	162	48	698	108	37.0	36.3	..	30	Breast-milk.
							31	2.96		205	61	884	118					
							29	2.36	....	...	...	....	106					
		May 22	....	5	..	3.29	31	2.52	.85	176	53	772	106	37.2	36.7	..	30	Do.
							32	2.31		161	49	706	96					
							$21\frac{1}{2}$	2.71	....	...	...	....	109					
		May 23	....	6	..	3.35	31	2.55	.89	172	51	745	111	37.0	37.0	..	30	Do.
							31	2.57		173	52	749	123					
							26	2.38	....	...	...	....	111					
20	F.	May 25	52	..	16	3.74	36	2.37	.75	183	49	738	111	36.6	36.6	4	..	Colostrum.
							43	2.23		172	46	694	109					
							$46\frac{1}{2}$	2.05	....	...	...	....	125					
		May 26	....	1	16	3.60	37	2.30	.77	174	48	722	126	37.8	37.9	3	30	Do.
							35	2.42		183	51	759	124					
							$43\frac{1}{2}$	2.48	....	...	...	....	132					
		May 27	....	2	12	3.54	36	2.77	.77	209	59	874	129	37.9	38.0	1	30	Do.
							34	2.66		201	57	841	127					
							$19\frac{1}{2}$	2.25	....	...	...	....	117					
		May 28	....	3	12	3.54	34	2.06	.82	148	42	619	111	36.7	37.0	1	..	Breast-milk.
							33	2.18		157	44	657	108					
							$19\frac{1}{2}$	2.65	....	...	...	....	112					
		May 29	....	4	12	3.62	38	2.38	.85	166	46	686	106	36.3	36.7	1	..	Do.
							30	2.30		161	44	665	111					
							30	2.28		159	44	657	109					
							16	2.36	....	...	...	....	114					
21	F.	May 25	50	..	$20\frac{1}{2}$	3.05	34	1.94	.72	155	51	714	116	36.7	36.6	3	..	Colostrum.
							33	2.02		161	53	742	119					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°C.	°C.	*h.* *m.*	
		1914.				25	1.58	....	...	...	....	111				
21 (Cont.)	F.	May 26	....	1 $20\frac{1}{2}$	2.92	35	1.66	0.72	132	45	626	121	36.9	36.9	2 30	Colostrum.
						38	1.75		140	48	664	120				
						$22\frac{1}{2}$	2.35	....	...	...	....	145				
		May 27	....	3 ..	2.98	37	2.79	.78	209	70	981	142	37.0	37.2	.. 30	Breast-milk commencing.
						32	2.76		206	69	967	136				
						$25\frac{1}{2}$	2.33	....	...	...	....	121				
		May 28	....	4 ..	3.02	32	2.03	.81	147	49	684	121	36.7	36.9	.. 30	Breast-milk.
						33	2.07		150	50	698	116				
						$26\frac{1}{2}$	2.99	....	...	...	....	126				
		May 29	....	5 ..	3.01	36	2.28	.81	166	55	772	120	36.7	36.6	.. 30	Do.
						36	2.63		191	63	888	129				
						23	3.34	....	...	...	....	124				
22	F.	June 1	49	1 $9\frac{1}{2}$	2.81	33	1.84	.71	149	53	723	120	36.7	37.2	4 30	Colostrum.
						33	2.60		210	75	1,019	126				
						$26\frac{1}{2}$	2.85	....	...	...	....	133				
		June 2	....	2 12	2.72	34	1.57	.71	127	47	632	115	36.9	36.7	.. 30	Do.
						38	1.59		128	47	637	113				
						$18\frac{1}{2}$	2.21	....	...	...	....	110				
		June 3	....	3 12	2.72	41	1.87	.75	144	53	716	108	36.9	36.7	.. 30	Breast-milk commencing.
						38	1.80		139	51	692	122				
						27	3.33	....	...	...	....	132				
		June 4	....	4 12	2.89	31	2.88	.87	198	69	943	130	36.8	36.8	.. 30	Breast-milk.
						31	3.41		234	81	1,114	132				
						18	3.03	....	...	...	....	132				
		June 5	....	5 12	2.86	38	2.23	.88	152	53	731	123	36.7	36.7	.. 30	Do.
						33	3.22		219	77	1,053	135				
						38	4.53	....	...	...	....	139				
		June 6	....	6 12	2.86	$18\frac{1}{2}$	3.79	....	...	...	....	144	36.7	37.0	.. 30	Breast-milk; sterile water 3 minutes before second preliminary period.
						40	3.27	.90	219	77	1,053	141				

23	F.	June 1	50.5	1	8	3.63	22	2.26	....	...	...	....	118	36.9	37.0	1	..	Colostrum.
							33	2.84	.79	210	58	864	124					
							33	2.20		163	45	671	118					
							29	2.63		195	54	802	123					
		June 2	....	2	12	3.60	$19\frac{1}{2}$	2.34	....	...	...	....	101	36.7	37.9	1	..	Do.
							40	2.76	.83	197	55	817	119					
							40	4.11		293	81	1,216	135					
		June 3	....	3	12	3.46	$32\frac{1}{2}$	3.12	....	...	...	....	134	37.2	37.1	..	30	Breasts beginning to fill; cried throughout observation, as if very hungry.
							36	2.83	.76	216	62	919	130					
							33	2.75		210	61	894	128					
							26	3.51		268	77	1,140	140					
		June 4	....	4	12	3.46	13	2.82	....	...	...	....	124	36.7	36.3	1	..	Breast-milk.
							39	2.68	.80	196	57	834	115					
							32	2.74		201	58	855	116					
							35	2.49		183	53	779	110					
		June 5	....	5	12	3.52	$33\frac{1}{2}$	3.21	....	...	...	....	134	36.8	36.8	2	..	Do.
							32	2.48	.80	182	52	765	116					
							38	2.94		216	61	908	127					
		June 6	....	6	12	3.52	15	2.92	....	...	...	....	112	36.8	36.7	1	..	Do.
							30	2.70	.88	184	52	773	118					
							46	4.19		285	81	1,197	132					
							34	2.84		193	55	811	119					
[3]24	M.	June 8	43	..	$20\frac{1}{2}$	2.35	23	1.36	....	...	...	....	124	36.6	35.4	..	..	No food.
							45	1.04	.77	79	34	434	125					
							64	1.10		83	35	456	124					
25	M.	June 8	51.5	..	13	3.37	$22\frac{1}{2}$	2.27	....	...	...	....	117	36.9	36.9	..	..	No feedings.
							38	2.24	.79	166	49	716	122					
							34	2.24		166	49	716	127					
		June 9	....	1	18	3.33	27	2.67	....	...	...	....	118	36.8	36.9	2	..	Colostrum.
							31	2.36	.76	180	54	783	121					
							31	2.25		172	52	748	121					
							35	2.59		198	59	861	125					
		June 10	....	2	12	3.35	24	2.45	....	...	...	....	130	36.8	36.8	..	30	Do.
							32	2.27	.78	170	51	736	127					
							35	2.71		203	61	879	139					
		June 11	....	3	12	3.26	$21\frac{1}{2}$	2.43	....	...	...	....	134	37.1	36.9	..	30	Breasts filling.
							35	2.25	.76	172	53	761	127					
							32	2.10		160	49	708	120					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]Died subsequently of inanition.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1914.				20	2.22	....	...	...	....	124				
25 (Cont.)	M.	June 12	....	4 12	3.37	32	2.18	0.87	150	45	647	124	36.8	36.9	1 ..	Breast-milk.
						35	2.38		163	48	703	124				
						$18\frac{1}{2}$	2.43	....	...	...	....	128				
		June 13	....	5 12	3.50	33	2.58	.92	170	49	717	129	36.7	37.0	.. 30	Do.
						34	2.59		170	49	717	129				
						$25\frac{1}{2}$	3.01	....	...	...	....	114				
		June 15	....	7 12	3.57	30	2.98	.94	193	54	804	123	36.9	37.0	.. 30	Do.
						36	3.60		233	65	971	135				
						29	2.67	....	...	...	....	132				
26	F.	June 10	50	4 ..	3.40	26	2.05	.78	153	45	657	117	36.7	37.0	2 ..	Breast-milk.
						38	2.84		212	62	910	119				
						34	2.03		152	45	652	116				
						36	3.37	....	...	...	....	133				
		June 11	....	5 ..	3.45	34	3.05	.84	215	62	915	121	36.9	37.3	.. 30	Do.
						35	2.49		176	51	749	117				
						$21\frac{1}{2}$	2.34	....	...	...	....	111				
		June 12	....	6 ..	3.52	33	2.11	.84	149	42	626	106	37.3	37.6	1 30	Do.
						26	3.81		269	76	1,130	124				
						40	2.48		175	50	735	118				
						17	2.82	....	...	...	....	129				
27	M.	June 16	52	.. 12	3.83	32	2.68	.76	205	54	813	134	37.6	37.1	.. ..	No food.
						35	2.54		194	51	770	130				
						23	2.97	....	...	...	....	119				
		June 17	....	1 12	3.74	32	2.63	.72	210	56	847	115	37.2	36.9	.. 30	Colostrum.
						32	2.61		208	56	839	118				
						$26\frac{1}{2}$	2.58	....	...	...	....	116				
		June 18	....	2 12	3.74	31	2.46	.69	201	54	810	116	37.1	37.3	.. 30	Do.
						31	2.32		190	51	766	115				

		June 19	....	3	12	3.52	$22\frac{1}{2}$	2.40	....	...	...	....	112	37.2	37.0	1	..	Breasts beginning to fill.
							33	2.64	.68	216	61	908	128					
							33	2.09		171	49	718	116					
		June 20	....	4	12	3.63	24	2.38	....	...	...	....	108	37.6	36.7	..	30	Breast-milk.
							35	2.19	.76	167	46	687	105					
							34	2.36		180	50	741	109					
		June 22	....	6	12	3.77	$32\frac{1}{2}$	3.19	....	...	...	....	134	37.2	36.9	..	30	Do.
							30	3.08	.86	213	56	852	130					
							32	2.68		186	49	744	124					
		June 23	....	7	12	3.83	27	2.98	....	...	...	....	120	37.2	36.9	..	30	Do.
							32	2.48	.88	169	44	671	125					
							35	2.57		175	46	694	120					
28	F.	June 18	50.5	1	4	3.49	23	2.58	....	...	...	....	124	36.9	37.1	16	..	Colostrum; sterile water 4 minutes before the observation.
							39	2.66	.77	201	58	848	132					
							30	2.94		222	64	937	131					
							34	1.94		147	42	620	123					
		June 19	....	2	..	3.60	$30\frac{1}{2}$	2.14	....	...	...	....	118	36.7	37.0	1	..	Breasts beginning to fill.
							33	2.13	.70	174	48	722	116					
							34	1.99		163	45	676	117					
							37	1.90		155	43	643	118					
29	F.	June 24	50	..	$11\frac{1}{2}$	3.63	30	2.88	....	...	...	....	123	37.2	37.4	4	..	Colostrum.
							41	2.18	.82	157	43	646	119					
							34	2.26		163	45	671	120					
		June 25	....	1	$11\frac{1}{2}$	3.52	25	2.45	....	...	...	....	122	37.7	37.7	4	..	Do.
							34	1.94	.78	145	41	609	113					
							42	3.01		225	64	945	121					
		June 26	....	2	12	3.32	$27\frac{1}{2}$	1.94	....	...	...	....	119	37.3	37.5	2	..	Do.
							35	1.99	.73	157	47	686	116					
							33	1.95		154	46	672	110					
							30	2.04		161	48	703	118					
		June 27	....	3	12	3.26	21	2.31	....	...	...	....	109	36.8	37.4	1	..	Breasts beginning to fill.
							38	2.04	.83	145	44	642	107					
							30	2.38		169	52	748	112					
							24	4.58		326	100	1,442	139					
		June 29	....	5	12	3.37	33	3.49	....	...	...	....	124	37.0	36.8	..	30	Breast-milk.
							28	2.38	.80	175	52	754	103					
							36	2.50		183	54	789	109					
							31	2.90		213	63	918	122					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h. m.*	
		1914.				$22\frac{1}{2}$	2.83	....	...	...	....	116				
29 (Cont.)	F.	June 30	....	6 12	3.46	37	2.22	0.81	161	47	685	109	36.9	37.1	1 ..	Breast-milk.
						40	2.52		183	53	779	117				
30	M.	June 25	51	1 1	3.43	27	2.42	....	...	...	....	125				
						34	1.75	.71	141	41	603	126	37.3	37.2	4 30	Colostrum.
						38	1.78		144	42	615	124				
						$19\frac{1}{2}$	2.00	....	...	...	....	107				
		June 26	....	2 ..	3.29	37	1.93	.71	156	47	684	112	37.0	36.9	.. 30	Breasts beginning to fill.
						35	1.77		143	43	627	102				
						$26\frac{1}{2}$	1.95	....	...	...	....	99				
		June 27	....	3 ..	3.26	38	1.83	.72	146	45	646	105	36.7	37.3	.. 30	Breast-milk.
						34	2.10		168	52	743	117				
						18	2.43	....	...	...	....	113				
		June 29	....	5 ..	3.32	34	2.22	.80	163	49	712	110	37.2	36.2	.. 30	Do.
						34	2.52		185	56	808	128				
						27	2.60	....	...	...	....	113				
		June 30	....	6 ..	3.32	33	2.18	.81	158	48	690	113	37.2	36.6	.. 30	Do.
						38	2.38		173	52	755	118				
						15	3.00	....	...	...	....	127				
31	M.	Oct. 19	53.5	4 ..	3.56	31	2.13	.81	155	44	649	118	....	37.1	1 ..	Breast-milk; breasts engorged on the preceding day.
						30	2.22		161	45	674	115				
						21	2.03	....	...	...	....	124				
32	M.	Oct. 20	47.5	.. 22	3.49	36	1.80	.65	147	42	620	127	36.8	37.2	4 30	Colostrum.
						33	1.67		137	39	578	128				
						17	2.36	....	...	...	....	115				
		Oct. 23	....	4 ..	3.35	36	1.73	.63	142	42	617	110	36.8	37.0	1 ..	Breast-milk; breasts engorged two days previous.
						37	1.74		142	42	617	111				
						22	2.29	....	...	...	....	128				
		Oct. 24	....	5 ..	3.41	36	2.08	.85	145	43	622	118	37.1	37.3	.. 30	Breast-milk.
						37	2.19		153	45	657	127				

33	M.	Oct. 26	52	2	12	3.66	$21\frac{1}{2}$	2.76	....	...	...	....	129	37.2	37.7	..	30	Colostrum and breast-milk; breasts engorged 5 hours earlier.
							32	2.38	.83	169	46	693	129							
							33	2.33		166	45	680	128							
		Oct. 27	....	3	12	3.74	$34\frac{1}{2}$	2.33	....	...	...	....	126	37.2	37.2	..	30	Breast-milk.
							52	2.10	.83	150	40	605	122							
		Oct. 28	....	4	12	3.70	$28\frac{1}{2}$	2.38	....	...	...	....	120	36.6	37.4	..	30	Do.
							36	2.13	.64	174	47	707	125							
							32	1.63		133	36	541	132							
		Oct. 29	....	5	12	3.76	$30\frac{1}{2}$	2.46	....	...	...	....	128	37.0	37.7	..	30	Do.
							33	2.18	.69	178	47	715	138							
							37	2.30		188	50	755	136							
		Oct. 30	....	6	12	3.71	$33\frac{1}{2}$	2.49	....	...	...	....	135	37.1	36.7	..	30	Do.
							49	2.03	.76	155	42	628	136							
		Oct. 31	....	7	12	3.78	22	2.75	....	...	...	....	140	37.1	37.0	..	30	Do.
							33	2.22	.69	182	48	728	148							
							33	2.49		204	54	816	143							
34	F.	Oct. 26	50.5	2	..	2.90	40	2.12	....	...	...	....	112	36.8	37.6	1	30	Colostrum and breast-milk.
							37	1.77	.74	138	48	657	119							
							39	1.66		130	45	619	112							
		Oct. 27	....	3	..	3.00	$31\frac{1}{2}$	2.29	....	...	...	....	120	36.3	36.7	1	30	Breast-milk.
							47	2.00	.74	156	52	729	121							
							43	1.94		151	50	706	125							
		Oct. 28	....	4	..	3.08	38	2.32	....	...	...	....	120	37.3	37.7	1	30	Do.
							42	2.10	.90	140	45	642	134							
							38	2.10		140	45	642	128							
		Oct. 29	....	5	..	3.16	$37\frac{1}{2}$	2.86	....	...	...	....	135	37.0	36.7	1	30	Do.
							38	2.05	.85	143	45	644	137							
							41	2.12		148	47	667	138							
35	F.	Oct. 30	54	1	5	4.41	$39\frac{1}{2}$	2.45	....	...	...	....	107	36.7	37.6	..	..	No food; sterile water 1 hour before the observation.
							36	2.47	.71	199	45	718	110							
							31	2.34		189	43	682	120							
		Oct. 31	....	2	..	4.33	$33\frac{1}{2}$	2.33	....	...	...	....	107	36.9	37.8	..	30	Colostrum.
							38	2.24	.73	177	41	646	111							
							43	2.41		190	44	693	118							
		Nov. 2	....	4	..	4.32	$40\frac{1}{2}$	2.64	....	...	...	....	109	37.0	37.0	1	..	Colostrum and breast-milk; also formula: fat, 2 p. ct.; lactose, 5 p. ct.; protein, 0.75 p. ct.; 1 oz. at feeding.
							33	2.29	.77	173	40	634	107							
							37	2.34		177	41	648	106							
		Nov. 3	....	5	..	4.29	$34\frac{1}{2}$	2.66	....	...	...	....	120	36.7	37.3	..	30	Breasts filled.
							32	2.44	.71	197	46	724	119							
							34	2.45		198	46	728	119							

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1914.				34	3.12	....	...	...	....	119				
35 (Cont.)	F.	Nov. 4	....	6 ..	4.35	31	2.55	0.82	183	42	665	112	37.0	37.2	.. 30	$1\frac{1}{2}$ oz. of formula used on Nov. 2.
						31	2.42		174	40	633	110				
		Nov. 5	....	7 ..	4.38	28	3.13	....	...	...	....	123				
						32	2.36	.74	184	42	667	116	37.2	37.3	.. 30	Same as on Nov. 4.
						28	2.42		189	43	685	112				
						$41\frac{1}{2}$	2.85	....	...	...	....	138				
36	M.	Nov. 2	53	.. 21	3.33	34	2.65	.75	205	62	891	137	37.6	37.6	1 ..	Colostrum.
						37	1.99		154	46	670	129				
						31	1.82	....	...	...	....	126				
37	F.	Nov. 3	46.5	.. 13	2.49	44	1.25	.80	92	37	487	113	36.9	36.8	.. ..	No food.
						46	1.43		105	42	556	125				
		Nov. 4	....	1 13	2.43	35	1.61	....	...	...	....	122	37.2	37.2	3 30	Colostrum.
						44	1.49	....	[3]115	47	618	121				
						23	1.64	....	...	...	....	128				
		Nov. 5	....	2 12	2.39	45	1.49	.75	115	48	625	130	37.1	37.7	.. 30	Breast-milk.
						45	1.56		120	50	652	136				
						$24\frac{1}{2}$	1.64	....	...	...	....	117				
		Nov. 6	....	3 12	2.39	47	1.34	.70	110	46	598	120	36.1	37.6	.. 30	Do.
						45	1.44		118	49	641	134				
		Nov. 7	....	4 12	2.44	$23\frac{1}{2}$	1.46	....	...	...	....	117	36.7	37.1	.. 30	Do.
						61	1.43	.73	113	46	608	124				
						40	2.75	....	...	...	....	123				
38	F.	Nov. 9	51.5	.. 9	4.20	34	2.15	.69	176	42	657	125	36.7	37.1	.. 30	Colostrum; regurgitated feeding within an hour.
						38	2.16		177	42	660	124				
						35	2.85	....	...	...	....	118				
		Nov. 10	....	1 9	3.90	35	2.06	.79	153	39	600	117	37.2	37.6	2 30	Colostrum.
						35	2.14		158	41	620	136				

		Nov. 11[4]	....	2	12	3.71	35½	2.74	....	...	...	....	141	37.2	38.2	..	30	Colostrum and breast-milk.
							35	2.21	.66	181	49	733	132					
							34	2.35		192	52	777	154					
39	F.	Nov. 9	50	..	8½	2.95	29	1.78	....	...	...	....	106	36.2	36.8	..	..	No food.
							35	1.92	.79	142	48	670	118					
							38	1.53		113	38	533	105					
							36	1.82		135	46	637	118					
		Nov. 10	....	1	8½	2.71	29	2.07	....	...	...	....	112	36.7	37.9	..	30	Colostrum.
							36	2.15	.78	161	59	801	125					
							38	1.86		139	51	692	184					
		Nov. 11	....	2	12	2.61	37	1.86	....	...	...	....	108	37.6	37.9	..	30	Breast-milk.
							36	1.75	.70	143	55	730	120					
							40	1.82		149	57	760	123					
		Nov. 12	....	3	..	2.72	30	2.10	....	...	...	....	113	36.7	38.0	..	30	Do.
							39	1.77	.75	137	50	682	113					
							35	1.77		137	50	682	117					
		Nov. 13	....	4	..	2.78	31	2.26	....	...	...	....	118	37.3	37.4	..	30	Do.
							37	1.83	.90	122	44	598	124					
							37	1.98		132	47	647	136					
		Nov. 14	....	5	..	2.85	27	2.78	....	...	...	....	133	37.0	37.7	..	30	Do.
							65	2.26	.83	161	56	774	137					
40	F.	Nov. 12	49.5	1	6½	2.86	28½	2.02	....	...	...	....	109	37.3	37.4	..	30	Colostrum.
							39	1.86	.76	142	50	683	116					
							41	1.89		144	50	692	118					
		Nov. 13	....	2	12	2.78	39½	3.83	....	...	...	....	159	38.3	39.4	..	30	Colostrum; high temperature due to hunger.
							43	4.19	.84	296	106	1,451	157					
		Nov. 14	....	3	12	2.75	35½	1.94	....	...	...	....	112	37.6	38.3	..	30	Breast-milk.
							48	1.79	.82	129	47	635	115					
							30	3.14		226	82	1,113	142					
		Nov. 16	....	5	12	2.81	31	2.19	....	...	...	....	103	36.7	37.1	..	30	Do.
							42	1.77	.77	134	48	650	106					
							38	1.85		140	50	680	112					
[5]41	M.	Nov. 16	51.5	..	4	3.91	32	2.25	....	...	...	....	101	35.7	36.0	..	..	No food.
							36	2.17	.95	139	36	543	107					
							33	2.05		131	34	512	101					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]Calculated by means of the average of the respiratory quotients obtained on the other days with this subject.

[4]No observation was made on the following day because of high temperature due to inanition.

[5]Died Nov. 20, 1914, probably of hemorrhagic disease of the new-born.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.		Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.			
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.*	*m.*	
		1914.				29	2.79	....	...	...	....	114					
42	F.	Nov. 17	54	.. 21	3.94	37	2.25	0.72	180	46	700	118	37.2	37.2	3	..	Colostrum.
						34	2.28		182	46	708	122					
						31	2.28	....	...	...	....	99					
		Nov. 18	....	1 21	3.87	36	2.15	.69	176	45	693	109	37.0	37.6	3	..	Do.
						35	2.14		175	45	689	115					
						30½	2.46	....	...	...	....	116					
		Nov. 19	....	3 ..	3.96	33	2.56	.80	188	47	729	122	37.0	37.8	..	30	Breast-milk.
						38	2.56		188	47	729	123					
						24	2.63	....	...	...	....	102					
		Nov. 20	....	4 ..	4.03	31	2.61	.89	176	44	674	114	36.8	37.3	..	30	Do.
						37	2.63		177	44	678	113					
						48½	3.62	....	...	...	....	134					
		Nov. 21	....	5 ..	4.05	32	2.74	.89	185	46	706	126	37.6	37.6	..	30	Do.
						33	2.42		163	40	622	125					
						26	3.12	....	...	...	....	135					
43	F.	Nov. 17	50	1 ..	3.71	34	2.58	.74	201	54	814	136	37.4	38.0	..	30	Colostrum.
						31	2.32		181	49	733	137					
						32	2.79		218	59	883	142					
						27½	3.08	....	...	...	....	126					
		Nov. 18	....	2 ..	3.62	35	2.14	.75	165	46	682	119	37.6	37.6	..	30	Breast-milk.
						30	2.34		181	50	748	128					
						33	2.33		180	50	744	132					
						34	1.96	....	...	...	....	108					
44	F.	Nov. 19	51	.. 2	3.57	39	1.77	.79	131	37	546	102	36.6	37.2	..	..	No food or water.
						40	1.91		141	39	588	103					
						43	2.60	....	...	...	....	107					
		Nov. 20	....	1 2	3.34	35	2.76	.82	198	59	861	123	37.0	37.6	3	30	Colostrum.
						36	3.13		225	67	978	131					

							36	1.93	....	...	...	....	99					
		Nov. 21	....	2 ..	3.24		39	1.89	.75	146	45	646	114	37.0	37.3	3	30	Colostrum; sterile water 4 minutes before the observation.
							31	1.88		145	45	642	110					
							30	2.14	....	...	...	....	115					
		Nov. 23	....	4 ..	3.18		36	2.07	.74	162	51	726	123	36.7	37.0	..	30	Breast-milk.
							37	2.14		167	53	749	124					
							$30\frac{1}{2}$	2.12	....	...	...	....	102					
45	F.	Nov. 23	46.5	.. $11\frac{1}{2}$	2.66		47	1.44	.83	103	39	520	99	36.7	36.0	..	..	No food.
							39	1.66		118	44	596	108					
							$35\frac{1}{2}$	2.01	....	...	...	....	122					
		Nov. 24	....	1 $11\frac{1}{2}$	2.46		42	1.34	.74	105	43	559	117	36.8	37.0	5	..	Colostrum; regurgitating in middle of preliminary period.
							42	1.44		112	46	596	113					
							28	1.95	....	...	...	....	118					
		Nov. 25	....	2 12	2.49		46	1.58	.74	123	49	651	104	36.7	36.7	..	30	Colostrum and breast-milk.
							44	1.62		126	51	667	109					
							26	2.95	....	...	...	....	132					
46	M.	Nov. 27	51.5	.. *48	3.83		41	2.59	.78	194	51	770	127	36.1	36.6	..	..	No food or water.
							34	2.15		161	42	639	117					
							35	2.49	....	...	...	....	133					
		Nov. 27	....	.. 5	....		40	1.82	.70	149	39	591	124	37.0	37.4	..	..	Do.
							40	1.89		155	40	615	128					
							32	2.25	....	...	...	....	116					
		Nov. 28	....	1 ..	3.59		40	2.01	.77	152	42	631	125	37.2	37.9	..	30	Colostrum.
							45	2.35		178	50	739	142					
							$48\frac{1}{2}$	2.23	....	...	...	....	132					
		Nov. 28	....	1 5	....		36	2.17	.82	156	43	647	142	37.1	37.9	1	30	Do.
							31	2.57		185	52	768	141					
							48	2.95	....	...	...	....	130					
		Nov. 30	....	3 ..	3.39		31	2.23	.72	178	53	764	107	37.3	37.4	..	30	Breast-milk.
							33	2.15		172	51	738	110					
							32	2.16	....	...	...	....	102					
		Dec. 1	....	4 ..	3.42		47	1.84	.70	150	44	641	103	37.6	36.9	..	30	Do.
							36	1.98		162	47	692	109					
							40	2.52	....	...	...	....	114					
		Dec. 2	....	5 ..	3.46		36	2.28	.84	161	47	685	115	37.3	37.3	..	30	Do.
							33	2.29		162	47	689	113					
							37	2.87	....	...	...	....	134					
		Dec. 3	....	6 ..	3.60		37	2.56	.82	184	51	763	133	36.7	37.0	..	30	Do.
							34	3.32		239	66	992	158					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

*Minutes.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1914.				30	2.36	....	...	...	....	115				
47	M.	Nov. 30	52	.. 5	3.51	44	1.91	0.81	139	40	586	106	37.8	37.2	.. ..	No food or water.
						34	2.01		146	42	616	108				
						35	2.11	....	...	...	....	120				
		Dec. 1	....	1 5	3.32	33	1.93	.68	158	48	690	126	37.7	37.6	10 30	Colostrum.
						40	2.01		164	49	716	133				
						33	2.11	....	...	...	....	110				
		Dec. 2	....	2 ..	3.16	34	1.99	.78	149	47	671	120	37.1	37.3	.. 30	Breast-milk.
						33	1.93		144	46	649	115				
						47	1.86	....	...	...	....	100				
		Dec. 3	....	3 ..	3.22	33	2.02	.75	156	48	693	103	37.0	36.7	.. 30	Do.
						35	1.95		151	47	671	107				
						35	3.19	....	...	...	....	119				
		Dec. 4	....	4 12	3.26	34	2.38	.74	186	57	823	119	36.7	37.1	.. 30	Do.
						33	2.04		159	49	704	122				
						23	2.66	....	...	...	....	128				
		Dec. 5	....	5 12	3.30	33	2.49	.80	183	55	803	135	37.2	37.2	.. 30	Do.
						45	2.36		173	52	759	136				
						55	3.46	....	...	...	....	132				
48	F.	Dec. 7	54.5	.. $22\frac{1}{2}$	4.55	24	2.98	.76	228	50	806	135	37.2	37.2	3 ..	Colostrum.
						34	3.37		257	56	908	145				
						29	2.79	....	...	...	....	129				
		Dec. 8	....	1 $23\frac{1}{2}$	4.42	30	2.76	.75	213	48	766	136	37.6	37.6	2 ..	Do.
						30	2.68		207	47	745	140				
						67	6.30	....	...	...	....	181				Colostrum and breast-milk; sterile water 3 minutes before the second preliminary.
		Dec. 9	....	3 ..	4.37	$18\frac{1}{2}$	3.83	....	...	...	....	168	37.9	38.9	2 ..	
						25	3.50	.67	286	65	1,036	150				
						26	2.86	....	...	...	....	125				
		Dec. 10	....	4 ..	4.39	37	2.51	.73	198	45	715	130	37.6	37.2	2 ..	Breast-milk.
						30	2.62		207	47	747	133				

		Dec. 11	....	5 ..	4.51	35	3.05	....	...	...	....	129	36.7	36.9	..	30	Do.
						37	2.74	.79	203	45	722	135					
						38	2.76		204	45	726	127					
		Dec. 12	....	6 ..	4.52	39	3.06	....	...	...	....	139	37.0	36.8	..	30	Do.
						34	2.52	.82	181	40	642	132					
						35	2.71		195	43	691	131					
		Dec. 14	....	8 ..	4.59	34	3.69	....	...	...	....	167	37.3	37.6	..	30	Do.
						35	3.12	.83	222	48	779	156					
						40	3.14		224	49	786	156					
49	F.	Dec. 8	47.5	.. *68	2.92	28	3.32	....	...	...	....	140	37.2	37.6	..	..	No food or water.
						36	2.45	.88	167	57	791	131					
						33	2.44		166	57	787	147					
		Dec. 9	....	1 ½	2.78	32	2.51	....	...	...	....	125	37.0	36.7	2	..	Colostrum and breast-milk.
						38	1.97	.75	152	55	745	113					
						30	2.06		159	57	779	117					
		Dec. 10	....	2 ..	2.72	37	2.24	....	...	...	....	124	37.1	37.4	..	30	Breast-milk.
						31	1.74	.68	142	52	706	108					
						36	1.72		141	52	701	114					
		Dec. 11	....	3 ..	2.72	28	2.16	....	...	...	....	105	36.7	36.7	..	30	Do.
						36	1.98	.78	148	54	736	111					
						32	1.76		132	49	657	114					
		Dec. 12	....	4 ..	2.75	25	1.97	....	...	...	....	95	36.9	37.0	..	30	Do.
						38	1.78	.79	132	48	650	114					
						35	1.71		127	46	626	114					
50	F.	Dec. 14	48.5	1 3	2.75	28	1.93	....	...	...	....	94	36.1	36.8	3	..	Colostrum.
						38	1.86	.76	142	52	700	89?					
51	M.	Dec. 15	52.5	.. 16	3.82	50	3.34	....	...	...	....	120	37.2	36.7	3	..	Colostrum.
						37	2.35	.73	185	48	734	108					
						33	1.91		151	40	599	99					
		Dec. 16	....	1 16	3.68	32	2.12	....	...	...	....	101	37.1	37.0	4	30	Do.
						36	2.10	.71	169	46	690	108					
						28	2.08		168	46	686	119					
		Dec. 17	....	2 12	3.64	42	2.06	....	...	...	....	97	36.8	37.0	..	30	Colostrum; breasts beginning to fill.
						33	1.95	.71	157	43	646	93					
						32	2.04		165	45	679	102					
		Dec. 18	....	4 ..	3.84	31	2.65	....	...	...	....	104	37.4	37.4	..	30	Breast-milk.
						34	2.49	.80	183	48	723	111					
						32	2.33		171	45	676	108					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

*Minutes.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h. m.*	
		1914.				37	2.76	....	...	...	....	116				
51 (Cont.)	M.	Dec. 19	....	4 12	3.84	39	2.46	0.85	172	45	680	109	37.0	37.0	.. 30	Breast-milk.
						39	2.35		164	43	648	113				
						26	2.33	....	...	...	....	126				
52	F.	Dec. 21	50	1 6	3.46	35	1.89	.82	136	39	579	124	37.3	37.8	3 ..	Colostrum.
						32	2.33		168	49	715	125				
						31	2.09	....	...	...	....	110				
		Dec. 22	....	2 12	3.61	32	1.80	.75	139	39	574	110	37.0	37.6	3 ..	Colostrum and breast-milk.
						38	1.96		151	42	624	120				
						45	2.25	....	...	...	....	108				
		Dec. 23	....	3 ..	3.59	33	1.91	.71	154	43	639	115	37.0	38.4	.. 30	Breast-milk.
						28	2.59		209	58	867	138				
						26½	2.02	....	...	...	....	98				
		Dec. 24	....	4 ..	3.56	33	1.75	.73	138	39	577	112	36.7	37.0	.. 30	Do.
						34	1.78		140	39	586	109				
53	M.	Dec. 28	47.5	1 ..	3.13	37	3.65	....	...	...	....	145	37.0	38.6	3 ..	Colostrum.
						40	4.71	.90	315	101	1,425	160				
						27	1.89	....	...	...	....	123				
		Dec. 29	....	2 ..	2.87	35	1.89	.76	144	50	689	128	37.8	37.7	3 ..	Colostrum; breasts beginning to fill; sterile water 9 minutes before the observation.
						38	1.86		142	49	679	124				
						32	3.13	....	...	...	....	112				
54	M.	Dec. 30	50	.. 6½	3.38	30	2.62	.83	187	55	806	111	36.0	36.7	.. ..	No food.
						33	2.00		142	42	612	101				
						28½	2.13	....	...	...	....	98				
		Dec. 31	....	1 6	3.31	34	1.73	.81	126	38	550	102	36.9	37.2	3 ..	Colostrum; sterile water 3 minutes before the observation.
						34	1.82		132	40	576	110				
		1915				42	2.00	....	...	...	....	113				
		Jan. 1	....	2 12	3.32	39	1.78	.72	142	43	620	120	37.4	37.0	3 ..	Colostrum; breasts beginning to fill.
						36	1.92		153	46	668	119				

		Jan. 2	....	3	12	3.20	21	2.34	....	...	...	....	113	37.1	37.0	..	30	Breast-milk.
							36	2.03	.76	155	48	692	118					
							34	1.99		152	48	679	109					
55	M.	Jan. 4	50	..	16	3.45	37½	2.54	....	...	...	....	126	36.6	37.2	1	..	Colostrum.
							37	1.95	.76	149	43	634	123					
							34	1.99		152	44	647	125					
56	M.	Jan. 5	51.5	3	..	3.19	29½	2.32	....	...	...	....	120	36.7	37.1	1	..	Breast-milk.
							42	1.93	.73	152	48	679	126					
		Jan. 6	....	4	..	3.19	29	2.88	....	...	...	....	141	36.7	37.0	..	30	Do.
							33	2.33	.81	169	53	754	119					
							34	2.03		147	46	656	120					
							33	2.07		150	47	670	118					
		Jan. 7	....	5	..	3.19	32	2.48	....	...	...	....	134	37.0	37.0	..	30	Do.
							33	2.29	.85	160	50	714	131					
							31	2.15		150	47	670	119					
		Jan. 8	....	6	..	3.13	31	2.75	....	...	...	....	131	36.6	....	..	30	Do.
							34	2.54	.88	173	55	783	140					
							33	2.42		165	53	747	133					
57	M.	Jan. 7	54	..	9½	3.90	36½	2.93	....	...	...	....	112	36.2	36.8	..	..	No food.
							33	1.91	.69	156	40	612	102					
							33	1.98		162	42	635	115					
		Jan. 8	....	1	9	3.59	33	2.15	....	...	...	....	109	37.6	37.1	3	30	Colostrum.
							36	1.88	.78	141	39	585	99					
							35	3.29		246	69	1,021	145					
		Jan. 9	....	2	..	3.55	35½	2.25	....	...	...	....	110	36.9	37.3	..	30	Colostrum; breasts beginning to fill.
							28	2.34	.71	189	53	791	130					
							30	2.74		221	62	925	120					
		Jan. 11	....	4	..	3.69	32½	2.58	....	...	...	....	102	36.7	37.0	1	..	Breast-milk.
							38	2.32	.80	170	46	691	121					
							35	2.26		166	45	675	116					
		Jan. 12	....	5	12	3.70	33	3.20	....	...	...	....	115	37.0	37.2	1	..	Breast-milk; sterile water 4 minutes before the observation.
							28	4.74	.83	338	91	1,374	148					
							25	4.85		345	93	1,402	154					
58	F.	Jan. 11	49	..	15	3.06	36½	2.35	....	...	...	....	120	37.1	37.0	..	30	Colostrum.
							34	1.82	.76	139	45	641	117					
							34	1.89		144	47	664	112					
		Jan. 12	....	1	10	2.96	30½	1.97	....	...	...	....	104	37.0	37.6	3	..	Do.
							35	1.71	.74	133	45	627	106					
							35	1.78		139	47	656	108					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{W^2}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h. m.*	
		1915.				22½	1.97	....	...	...	....	110				
58	F.	Jan. 14	....	3 12	2.96	35	1.89	0.78	141	48	665	113	37.1	37.0	.. 30	Breast-milk.
(Cont.)						34	2.06		154	52	726	106				
						22½	2.96	....	...	...	....	129				
59	F.	Jan. 15	52	1 1½	3.62	31	1.94	.75	150	41	620	115	37.1	37.4	3 30	Colostrum.
						33	2.05		158	44	653	131				
						34	2.61	....	...	...	....	119				
		Jan. 16	....	2 ..	3.57	34	1.85	.71	149	42	621	108	36.7	37.2	1 ..	Do.
						33	2.02		163	46	679	117				
						38	3.73	....	...	...	....	132				
		Jan. 19	....	5 ..	3.66	20	2.94	.81	213	58	873	132	36.7	36.7	.. 30	Breast-milk.
						32	2.21		160	44	656	120				
						35	2.42	....	...	...	....	132				
[3]60	M	Jan. 15	52	1 20½	3.81	38	2.10	.74	164	43	653	130	36.7	36.8	1 ..	Colostrum.
						27	2.73		213	56	849	142				
						31½	2.04	....	...	...	....	123				
		Jan. 18	....	4 12	3.60	34	1.78	.71	144	40	598	116	37.0	37.0	.. 30	Breast-milk.
						31	1.90		153	43	635	118				
						32	1.86	....	...	...	....	119				
61	M.	Jan. 20	49.5	.. 2½	3.26	37	1.70	.80	125	38	553	121	37.0	36.1	.. ..	No food.
						36	1.63		120	37	531	120				
						40	1.74	....	...	...	....	101				
		Jan. 21	....	1 2½	2.75	38	1.53	.73	121	44	596	124	36.7	36.7	4 ..	Colostrum.
						42	1.57		124	45	611	120				
						31½	1.75	....	...	...	....	119				
		Jan. 22	....	2 ..	2.69	40	1.62	.77	122	45	610	128	37.0	37.0	2 30	Do.
						36	1.55		117	43	585	129				
						36	3.07	....	...	...	....	115				
62	M.	Jan. 26	49.5	.. 17½	3.36	30	2.28	.78	171	51	740	121	36.7	36.7	4 30	Colostrum.
						37	1.80		135	40	584	118				

		Jan. 27	....	1	18	3.22	22½	2.29	....	...	...	....	107	37.0	36.7	..	30	Do.
							34	2.06	.78	154	48	684	116					
							31	1.95		146	45	649	118					
		Jan. 28	....	3	..	3.27	36½	4.44	....	...	...	....	146	36.7	37.7	..	30	Breast-milk.
							35	1.90	.67	155	47	683	126					
							24	3.00		245	75	1,079	159					
		Jan. 29	....	4	..	3.27	33	2.25	....	...	...	....	120	37.6	36.9	..	30	Do.
							35	1.71	.72	136	42	599	114					
							37	1.83		146	45	643	112					
		Jan. 30	....	5	..	3.26	30	2.66	....	...	...	....	124	36.7	36.7	..	30	Do.
							33	1.82	.82	131	40	580	115					
							38	1.91		137	42	606	122					
63	F.	Feb. 3	47.5	..	23½	2.50	29	2.26	....	...	...	....	113	36.4	36.1	5	30	Colostrum.
							33	1.56	.68	128	51	674	112					
							39	1.75		143	57	753	106					
		Feb. 4	....	1	23	2.36	28	1.95	....	...	...	....	112	36.8	36.8	..	30	Do.
							40	1.61	.74	126	53	692	118					
							37	1.61		126	53	692	118					
		Feb. 5	....	3	..	2.37	25½	1.81	....	...	...	....	118	36.8	37.6	1	..	Do.
							39	1.34	.71	108	46	590	127					
							45	1.36		110	46	601	123					
		Feb. 6	....	4	..	2.32	23	1.98	....	...	...	....	116	37.0	37.0	1	..	Breast-milk.
							43	1.60	.74	125	54	694	113					
							37	1.65		129	56	717	107					
64	F.	Feb. 4	48	..	6½	3.37	23	2.40	....	...	...	....	121	36.7	36.8	..	..	No food or water.
							39	1.86	.82	134	40	578	98					
							35	1.70		122	36	526	97					
		Feb. 5	....	1	5½	3.00	33	2.36	....	...	...	....	122	36.7	36.9	..	30	Colostrum.
							42	2.10	.70	172	57	804	117					
							37	1.99		163	54	762	106					
		Feb. 6	....	2	..	2.90	25	2.18	....	...	...	....	111	37.1	37.0	..	30	Do.
							37	1.80	.68	147	51	700	127					
							43	1.77		145	50	690	122					
		Feb. 8	....	4	12	3.26	24	2.53	....	...	...	....	136	36.9	37.0	..	30	Breast-milk.
							37	2.08	.78	156	48	690	127					
							34	1.94		145	44	642	131					
65	F.	Feb. 8	49	..	15½	2.61	36½	1.84	....	...	...	....	105	37.0	36.6	3	..	Colostrum.
							40	1.68	.77	127	49	648	106					
							31	1.97		149	57	760	123					

[1]The ages given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]Negro.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt{p^2}$).		Beginning of observation.	End of observation.		
			cm.	*d.* *h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h.* *m.*	
		1915.				29	2.03	....	...	...	....	129				
65 (Cont.)	F.	Feb. 9	....	1 15	2.50	40	1.71	0.70	140	56	737	125	37.0	37.1	.. 30	Colostrum.
						40	1.55		127	51	668	127				
						26	2.01	....	...	...	....	133				
		Feb. 10	....	2 12	2.52	42	1.73	.72	138	55	723	134	37.0	37.6	.. 30	Colostrum and breast-milk.
						35	1.70		136	54	712	139				
						23	2.17	....	...	...	....	124				
		Feb. 11	....	3 12	2.64	40	1.73	.77	131	50	665	121	36.7	36.8	1 30	Breast-milk.
						35	1.61		122	46	619	120				
						36	2.17	....	...	...	....	101				
66	M.	Feb. 9	51	.. 14	3.19	32	1.52	.76	116	36	518	103	36.1	36.6	.. 30	Colostrum.
						39	1.66		127	40	567	103				
						25	2.62	....	...	...	....	123				
		Feb. 10	....	1 $14\frac{1}{2}$	3.06	39	1.85	.79	137	45	631	115	36.7	36.7	.. 30	Do.
						41	1.83		136	44	627	122				
						27	2.71	....	...	...	....	136				
		Feb. 11	....	2 12	3.08	35	1.78	.77	135	44	619	126	36.7	37.1	.. 30	Breast-milk.
						39	1.83		138	45	633	122				
						42	2.31	....	...	...	....	129				
		Feb. 12	....	3 12	3.09	40	1.80	.67	147	48	671	127	37.0	37.0	1 ..	Do.
						38	1.85		151	49	689	134				
						$29\frac{1}{2}$	2.36	....	...	...	....	132				
		Feb. 13	....	4 12	3.15	35	2.06	.87	141	45	635	137	36.9	36.8	.. 30	Do.
						34	1.98		136	43	613	130				
						$33\frac{1}{2}$	4.12	....	...	...	....	135				
67	M.	Feb. 12	54	.. 5	4.99	32	4.07	.87	279	56	927	141	37.1	36.8	.. ..	No food or water.
						29	3.60		247	49	821	137				
						34	2.61	....	...	...	....	123				
		Feb. 13	....	1 9	4.62	32	2.61	.81	189	41	661	121	37.0	37.1	1 30	Colostrum.
						34	2.68		195	42	682	130				

		Feb. 15	....	3	12	4.86	29	2.46	....	...	...	....	123	37.3	37.1	..	30	Colostrum and breast-milk.
							34	2.81	.77	212	44	719	123					
							36	2.78		210	43	712	127					
		Feb. 16	....	4	..	4.85	29	2.92	....	...	...	....	117	37.0	37.0	..	30	Breast-milk.
							33	2.73	.82	196	40	664	115					
							31	2.81		202	42	685	119					
							34	1.59	....	...	...	....	106					
68	M.	Feb. 16	46	1	11½	2.31	39	2.05	.72	164	71	911	126	37.0	36.9	3	30	Colostrum.
							34	1.87		149	65	828	128					
							27½	1.81	....	...	...	....	122					
		Feb. 17	....	2	12	2.18	26	2.01	.76	154	71	890	123	36.7	37.1	1	..	Breasts filled.
							37	2.42		185	85	1,069	141					
							29	1.47	....	...	...	....	110					
		Feb. 18	....	3	12	2.13	41	1.30	.67	106	50	620	114	36.7	36.7	..	30	Breast-milk.
							51	1.21		99	46	579	115					
							32	1.44	....	...	...	....	104					
		Feb. 19	....	4	12	2.11	65	1.27	.68	104	49	612	109	37.2	36.7	..	30	Do.
							34	2.44	....	...	...	....	126					
69	M.	Feb. 17	50	..	7	3.52	36	2.37	.79	176	50	739	111	36.7	36.7	..	..	No food or water.
							32	1.95		144	41	605	112					
							44	2.24	....	...	...	....	103					
		Feb. 18	....	1	7	3.35	38	1.86	.68	152	45	658	104	37.2	37.2	..	30	Colostrum.
							34	1.59		130	39	563	114					
							20½	2.90	....	...	...	....	124					
		Feb. 19	....	2	12	3.37	32	2.08	.76	159	47	685	105	37.1	36.7	..	30	Breast-milk.
							29	2.09		160	47	690	118					
							23	2.87	....	...	...	....	111					
70	M.	Feb. 23	51	1	3½	3.66	26	3.18	.74	248	68	1,016	114	36.7	37.0	3	..	Colostrum.
							36	1.92		150	41	615	107					
							30	3.14	....	...	...	....	116					
		Feb. 24	....	2	..	3.63	26	2.03	.68	166	46	683	103	37.0	37.3	..	30	Colostrum and breast-milk; breasts filling.
							36	2.02		165	45	679	97					
							35	2.19	....	...	...	....	108					
		Feb. 25	....	3	..	3.46	29	2.23	.79	165	48	702	115	37.0	37.0	..	30	Breasts filled.
							16	3.64		270	78	1,149	125					
							30	2.10		156	45	664	111					
							33	2.33	....	...	...	....	99					
71	M.	Feb. 23	53.5	2	..	3.92	29	2.52	.72	201	51	785	112	37.1	36.8	4	..	Colostrum.
							35	2.14		171	44	668	111					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{w^2}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h. m.*	
		1915.				34	3.58	....	...	...	....	119				
71 (Cont.)	M.	Feb. 24	....	3 ..	3.94	28	3.28	0.83	234	59	911	118	37.0	37.0	.. 30	Colostrum and breast-milk; breasts almost filled.
						31	2.85		203	52	790	134				
						34	3.16	....	...	...	....	120				
		Feb. 25	....	4 ..	4.00	26	3.44	.81	250	63	962	119	36.4	36.8	.. 30	Breast-milk.
						34	2.38		173	43	665	100				
						31	2.57	....	...	...	....	110				
72	M.	Mar. 1	50.5	2 12	3.29	35	1.82	.68	149	45	654	110	36.7	36.7	1 ..	Formula: fat, 2 p. ct.; lactose, 5 p. ct.; protein, 0.75 p. ct.; 1 oz. at feeding.
						33	2.00		164	50	719	110				
						$34\frac{1}{2}$	2.33	....	...	...	....	103				
73	M.	Mar. 3	50	.. 7	3.63	35	2.25	.80	165	45	679	102	36.9	36.7	.. ..	No food.
						31	2.21		162	45	667	109				
						20	2.82	....	...	...	....	131				
		Mar. 4	....	1 7	3.44	35	2.33	.73	184	53	783	129	36.6	37.1	3 ..	Colostrum.
						32	2.25		178	52	757	133				
						22	2.97	....	...	...	....	142				
		Mar. 5	....	2 12	3.30	37	2.27	.81	165	50	724	131	37.0	37.3	1 ..	Breasts filled about 24 hours before this observation.
						25	3.41		248	75	1,088	162				
						21	2.80	....	...	...	....	120				
		Mar. 6	....	3 12	3.40	34	2.31	.82	166	49	712	124	36.1	36.8	.. 30	Breast-milk.
						32	2.38		171	50	734	117				
74	M.	Mar. 8	52	.. 22	3.58	26	2.88	.74	...	...	....	118	36.8	36.9	1 ..	Formula: fat, 2 p. ct.; lactose, 5 p. ct.; protein, 0.75 p. ct.; 1 oz. at feeding.
						28	2.70		211	59	879	117				
						21	2.43	....	...	...	....	91				
		Mar. 9	....	1 22	3.63	33	1.96	.75	151	42	621	94	36.8	36.9	.. 30	Same as on Mar. 8.
						31	2.07		160	44	658	94				
						$34\frac{1}{2}$	2.16	....	...	...	....	100				
75	M.	Mar. 8	47.5	1 12	2.65	44	1.65	.70	135	51	682	104	36.4	36.8	1 ..	Colostrum; breasts beginning to fill.
						41	1.57		128	48	646	96				

		Mar. 9	....	2	12	2.64	34	1.84	....	...	...	....	114	37.0	37.1	..	30	Breast-milk and colostrum.
							45	1.67	.70	137	52	695	113					
							44	1.77		145	55	736	109					
		Mar. 10	....	3	12	2.69	19	2.40	....	...	...	....	118	36.7	36.7	..	30	Breast-milk.
							34	2.01	.75	155	58	775	116					
							31	1.94		150	56	750	113					
76	M.	Mar. 11	50	..	13	3.16	23	2.53	....	...	...	....	110	36.7	36.7	5	..	Colostrum.
							35	1.70	.76	130	41	586	102					
							35	1.89		144	46	649	100					
77	F.	Mar. 13	53	..	16	3.83	19	2.56	....	...	...	....	122	36.8	37.1	3	30	Colostrum.
							40	3.02	.89	204	53	810	133					
78	M.	Mar. 15	47	..	11½	2.48	25	1.87	....	...	...	....	125	36.0	36.9	..	..	No food.
							44	1.39	.68	114	46	603	100					
							45	1.27		104	42	550	102					
79	F.	Mar. 16	52.5	..	3½	4.14	25½	3.44	....	...	...	....	127	37.0	36.8	..	..	No food.
							36	2.03	.78	152	37	571	119					
							32	2.06		154	37	579	113					
		Mar. 17	....	..	22	3.97	27	2.60	....	...	...	....	117	37.0	37.2	3	..	Colostrum.
							30	2.10	.68	172	43	664	124					
							31	2.34		191	48	737	114					
		Mar. 18	....	1	22½	3.89	25	2.76	....	...	...	....	121	37.3	36.8	..	30	Colostrum and breast-milk.
							31	2.32	.76	177	46	694	127					
							30	2.48		189	49	741	126					
		Mar. 19	....	3	..	3.83	34½	2.43	....	...	...	....	115	37.2	37.1	..	30	Do.
							32	2.42	.76	185	48	734	115					
							31	2.28		174	45	690	106					
80	M.	Mar. 19	51.5	..	[3]1½	3.47	26½	2.20	....	...	...	....	112	35.9	37.0	..	..	No food or water.
							60	2.14	.75	[4]155	45	657	116					
							60	1.76	.78	[4]128	37	542	109					
							62	3.99	.90	[4]290	84	1,229	146					
							31	3.60	....	...	...	....	141					Sterile water a few minutes before the second preliminary period.
							61	2.39	.78	[4]174	50	737	135					
		Mar. 22	....	3	..	3.37	29	3.54	....	...	...	....	127	37.3	37.3	..	30	Colostrum and breast-milk; mostly breast-milk.
							31	2.81	.75	217	64	935	137					
							33	2.35		181	54	780	124					
81	F.	Mar. 22	50	..	3½	3.29	22	2.59	....	...	...	....	126	36.9	36.9	..	..	No food or water.
							34	2.31	.77	175	53	768	125					
							34	2.21		167	51	732	114					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]For the age from period to period, see table 10, p. 81.

[4]The average respiratory quotient obtained during the entire period of observation has been used in computing the heat-production.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{n^2}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h. m.*	
						$26\frac{1}{2}$	1.58	....	...	...	....	102				
		1915.				68	1.28	0.76	[4]95	35	470	101				
82	M.	Mar. 23	49	.. $3\ 2\frac{1}{2}$	2.74	61	1.60	.78	[4]119	43	589	107	36.7	36.2	.. ..	No food or water.
						60	1.75	.83	[4]130	47	644	111				
						60	1.77	.80	[4]131	48	649	106				
						31	2.50	....	...	...	....	132				
						60	2.06	.80	[4]143	38	577	130				
						60	2.21	.90	[4]153	41	617	131				
						58	2.22	.83	[4]154	41	621	138				
83	M.	Mar. 24	52	.. $3\ 2$	3.73	63	2.20	.83	[4]152	41	613	130	36.6	37.9	.. ..	No food or water.
						61	2.24	.85	[4]155	42	625	132				
						57	2.39	.79	[4]166	45	669	143				
						57	3.55	.99	[4]246	66	992	156				
						$27\frac{1}{2}$	3.69	....	...	...	....	150				
						34	2.51		200	58	847	134				
		Mar. 25	....	1 $2\frac{1}{2}$	3.47	30	2.00	.72	160	46	678	125	37.3	37.3	3 30	Colostrum.
						36	1.98		158	46	669	118				
						20	4.35	....	...	...	....	138				
		Mar. 30	....	6 ..	3.74	42	2.36	.76	180	48	726	133	37.1	37.1	.. 30	Breast-milk.
						35	2.54		194	52	782	122				
						$18\frac{1}{2}$	2.89	....	...	...	....	119				
						65	1.82	.76	[4]133	32	504	109				
						50	1.81	.83	[4]133	32	504	108				
84	F.	Mar. 26	54	.. $3\ 1\frac{1}{2}$	4.11	75	2.26	.80	[4]166	40	629	129	36.1	36.9	.. ..	No food or water.
						59	3.09	.86	[4]227	55	860	139				
						62	2.70	.83	[4]198	48	750	128				
						55	2.02	.75	[4]148	36	561	123				
						58	2.04	.77	[4]150	36	568	117				

		Mar. 29	....	3	..	3.74	23	2.35	....	...	...	....	109	37.0	36.9	..	30	Colostrum and breast-milk; mostly breast-milk.
							34	2.22	.76	170	45	685	121					
							34	2.05		157	42	633	115					
85	M.	Mar. 26	52	..	9	3.52	$22\frac{1}{2}$	2.35	....	...	...	....	102	36.7	36.9	..	..	No food or water.
							32	2.19	.82	157	45	660	110					
							30	2.00		144	41	605	109					
86	F.	Mar. 30	51	..	$5\frac{1}{2}$	3.32	$30\frac{1}{2}$	1.81	....	...	...	....	101	35.8	37.3	..	..	No food.
							40	1.55	.75	120	36	524	103					
							42	1.86		144	43	629	113					
		Apr. 2	....	3	12	3.06	21	2.83	....	...	...	....	104	36.7	36.7	..	30	Breast-milk.
							40	1.95	.70	159	52	733	97					
							38	1.91		156	51	719	98					
							22	3.35	....	...	...	....	116					
							64	2.06	.79	[4]141	36	549	115					
							55	2.71	1.05	[4]186	47	724	132					
87	M.	Mar. 31	51	..	[3]$1\frac{1}{4}$	3.94	62	3.78	.90	[4]259	66	1,008	145	36.6	38.1	..	..	No food.
							61	2.42	.81	[4]166	42	646	124					
							64	2.18	.76	[4]150	38	584	121					
							60	2.27	.84	[4]156	40	607	125					
							41	3.70	.96	[4]254	64	988	143					
							20	3.00	....	...	...	....	110					
		Apr. 1	....	1	$5\frac{1}{4}$	3.72	37	1.99	.70	163	44	660	113	37.1	37.2	3	..	Colostrum.
							34	2.08		170	46	688	117					
							34	2.19		179	48	725	117					
							$21\frac{1}{2}$	2.23	....	...	...	....	106					
88	F.	Apr. 2	47.5	..	$8\frac{1}{2}$	2.62	39	1.57	.75	121	46	617	97	37.1	36.6	..	..	No food.
							40	1.59		123	47	628	95					
							20	2.97	....	...	...	....	116					
89	M.	Apr. 20	49.5	..	$7\frac{1}{2}$	3.24	34	1.59	.74	124	38	549	107	36.7	36.7	..	..	No food.
							38	1.63		127	39	562	115					
		Apr. 21	....	1	$6\frac{1}{2}$	3.12	17	3.21	....	...	...	....	120	36.8	36.9	5	..	Colostrum.
							35	1.66	.76	127	41	577	112					
							38	1.83		140	45	636	115					
		Apr. 22	....	2	12	3.08	24	2.20	....	...	...	....	118	36.7	37.1	1	..	Colostrum and breast-milk; breasts beginning to fill.
							36	2.05	.75	158	51	725	129					
							35	1.89		146	47	670	123					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]For the age from period to period, see table 10, p. 81.

[4]The average respiratory quotient obtained during the entire period of observation has been used in computing the heat-production.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{(n^2)}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		°*C.*	°*C.*	*h. m.*	
		1915.				30½	3.25	....	...	...	....	139				
89 (Cont.)	M.	Apr. 23	....	3 12	3.18	34	2.05	0.78	153	48	686	129	36.7	37.1	1 ..	Breast-milk.
						33	2.25		168	53	753	123				
						27	5.16		386	121	1,731	162				
						54	4.41	....	...	...	....	164				
		Apr. 26	....	6 12	3.16	37	2.92	.76	223	71	1,005	133	37.2	36.7	.. 30	Do.
						32	2.48		189	60	851	134				
						23	2.32	....	...	...	....	124				
[3]90	M.	Apr. 20	50	.. 20½	3.15	35	2.21	.78	165	52	743	121	36.8	36.7	5 30	Colostrum.
						33	1.95		146	46	658	116				
						35	2.04		153	49	689	115				
						27½	2.29	....	...	...	....	92				
		Apr. 21	....	1 20½	3.07	35	1.77	.73	140	46	642	88	36.7	36.7	3 30	Do.
						35	1.77		140	46	642	88				
						38	1.88		148	48	679	93				
						18½	1.88	....	...	...	....	80				
		Apr. 22	....	3 ..	2.92	45	1.77	.76	135	46	640	82	37.0	36.7	4 ..	Colostrum and breast-milk; breasts filling; sterile water 3 minutes before the observation.
						44	1.88		144	49	682	87				
						17½	2.37	....	...	...	....	122				
91	F.	Apr. 23	49.5	.. 13	3.33	39	1.89	.79	140	42	609	113	37.4	37.4	.. ..	No food.
						33	2.20		163	49	709	120				
						21	2.60	....	...	...	....	115				
		Apr. 24	....	1 17	3.21	39	1.92	.76	147	46	656	105	36.7	36.8	.. 30	Colostrum and breast-milk.
						31	2.09		160	50	714	96				
						33	1.93		147	46	656	104				
						19½	2.77	....	...	...	....	107				
92	F.	Apr. 24	51	.. 3½	3.78	41	2.34	.86	162	43	648	114	36.4	36.7	.. ..	No food.
						38	2.26		157	42	628	112				
						20½	3.34	....	...	...	....	136				
		Apr. 26	....	2 ..	3.52	33	3.02	.82	217	62	916	126	36.9	37.3	.. ..	No food for at least 5 hours before the observation.
						35	2.21		159	45	671	112				

						17½	3.29	....	...	...	....	146					
						60	2.69	.83	[5]195	55	819	137					
						62	1.86	.77	[5]135	38	567	132					
						55	2.01	.79	[5]146	41	613	141					
93	M.	Apr. 27	50.5	..*[4]43	3.53	60	2.69	.87	[5]195	55	819	137	36.8	36.8	..	..	No food or water.
						62	1.89	.76	[5]137	39	576	131					
						60	1.89	.77	[5]137	39	576	119					
						59	2.07	.86	[5]150	42	630	127					
						18	3.30	....	...	...	....	135					
						61	2.09	.76	[5]150	47	670	126					
						60	2.16	.87	[5]155	48	692	123					
						58	1.89	.81	[5]136	43	607	117					
[6]94	M.	Apr. 28	50	..*[4]56	3.20	64	2.12	.75	[5]152	48	679	126	36.3	37.2	..	..	No food or water.
						59	3.24	.96	[5]233	73	1,040	150					
						65	2.29	.80	[5]165	52	737	135					
						59	2.07	.79	[5]149	47	665	126					
						33½	2.53	....	...	...	....	125					
		Apr. 30	....	2 ..	2.89	35	2.02	.77	153	53	729	118	37.1	37.7	4	..	Colostrum.
						35	3.07		232	80	1,105	136					
						16½	2.47	....	...	...	....	142					
						59	1.90	.89	[5]135	48	652	144					
						60	1.54	.80	[5]110	39	531	119					
						62	1.65	.84	[5]117	41	565	132					
95	F.	May 1	46.5	..*[4]59	2.84	61	1.71	.83	[5]122	43	589	136	35.6	36.8	..	..	No food.
						59	1.41	.70	[5]100	35	483	123					
						65	1.58	.84	[5]113	40	546	127					
						54	2.09	.93	[5]149	52	720	145					
						22	2.54	....	...	...	....	120					
						59	1.87	.93	[5]128	40	569	111					
						67	1.75	.85	[5]120	37	533	110					
						61	1.65	.91	[5]113	35	502	99					
96	F.	May 3	51.5	..*[4]58	3.23	59	1.95	.89	[5]134	41	596	111	36.2	36.9	..	..	No food.
						60	1.75	.80	[5]120	37	533	107					
						69	1.88	.86	[5]129	40	573	107					
						58	2.09	.86	[5]143	44	636	125					

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]Pallid infant. Three-quarters of an hour was required for its resuscitation after birth.

[4]For the age from period to period, see table 10, p. 81.

[5]The average respiratory quotient obtained during the entire period of observation has been used in computing the heat-production.

[6]Negro. *Minutes.

TABLE 9.—*Results of observations on the gaseous exchange of new-born infants*—Continued.

Subject No.	Sex.	Date.	Length.	Age in days and hours.[1]	Weight without clothing.	Duration of period.	Carbon dioxide produced per hour.[2]	Respiratory quotient.	Heat produced (computed) per 24 hours.			Average pulse-rate.	Rectal temperature.		Time between feeding and observation.	Food.
									Total.	Per kilogram.	Per sq. m. (Lissauer, $10.3\sqrt[3]{(1)^2}$).		Beginning of observation.	End of observation.		
			cm.	*d. h.*	*kg.*	*min.*	*gm.*		*cal.*	*cal.*	*cal.*		*°C.*	*°C.*	*h. m.*	
						30	2.54	....	...	...	....	117				
						60	1.82	0.85	[4]127	45	617	108				
		1915.				60	1.75	.84	[4]122	43	592	126				
97	F.	May 6	48	.. [3]1½	2.82	69	1.58	.82	[4]110	39	534	114	35.7	36.4	.. ..	No food.
						56	1.61	.87	[4]113	40	549	112				
						62	1.65	.87	[4]115	41	558	118				
						58	1.84	.86	[4]129	46	626	135				
						55	1.80	.86	[4]126	45	612	125				
						30	1.88	....	...	...	....	103				
						55	1.33	.77	[4] 96	34	462	100				
						63	1.93	.90	[4]139	49	668	122				
98	F.	May 7	47.5	.. [3]1½	2.86	56	2.22	.90	[4]160	56	769	123	35.7	36.7	.. ..	No food.
						61	1.50	.74	[4]108	38	519	106				
						60	1.37	.74	[4] 99	35	476	106				
						72	1.38	.79	[4] 99	35	476	101				
						63	1.50	.85	[4]108	38	519	102				
						28	3.32	....	...	...	....	124				
						59	2.09	.79	[4]143	40	596	111				
						60	1.78	.83	[4]122	34	508	103				
99	M.	May 11	51.5	.. [3]1¼	3.58	59	3.09	.93	[4]212	59	883	133	36.6	37.2	.. ..	No food.
						76	2.33	.90	[4]160	45	667	117				
						63	2.00	.83	[4]137	38	571	113				
						56	2.81	.89	[4]193	54	804	126				
						53	3.25	.87	[4]223	62	929	139				
						19	4.45	....	...	...	....	134				
						70	3.47	.90	[4]230	49	801	128				
						64	3.43	.98	[4]227	49	791	139				
100	M.	May 13	54	..*[3]50	4.65	57	4.36	1.00	[4]289	62	1,007	141	36.6	37.7	.. ..	No food.
						63	2.86	.85	[4]190	41	662	126				
						56	2.96	.87	[4]196	42	683	139				
						61	2.81	.91	[4]186	40	648	130				
						59	3.12	.82	[4]207	45	721	140				

101	M.	May 17	51.5	..*[3]47	3.88	25	3.72	....	...	...	....	158	36.4	36.9	.. ..	No food.
						63	2.34	.89	[4]158	41	622	134				
						60	2.69	1.00	[4]181	47	713	145				
						68	2.73	.94	[4]184	47	724	128				
						58	1.90	.82	[4]128	33	504	114				
						58	1.87	.81	[4]126	32	496	109				
						61	2.27	.88	[4]153	39	602	123				
						57	2.29	.86	[4]154	40	606	116				
102	M.	May 19	47.5	.. [3]1¾	2.84	28	2.36	....	...	...	....	112	35.7	37.4	.. ..	No food.
						64	1.76	.83	[4]127	45	614	115				
						59	1.55	.80	[4]111	39	536	121				
						61	1.43	.82	[4]103	36	498	119				
						61	1.49	.78	[4]107	38	517	122				
						73	2.19	.88	[4]157	55	758	135				
						61	1.89	.80	[4]136	48	657	134				
						58	2.28	.81	[4]164	58	792	139				
103	F.	May 21	49	. *[3]45	3.29	31	3.10	....	...	...	....	123	36.6	38.4	.. ..	No food.
						61	2.25	.89	[4]156	47	684	125				
						60	1.87	.78	[4]130	40	570	125				
						58	2.63	.91	[4]182	55	798	149				
						63	2.96	.85	[4]205	62	899	163				
						64	2.15	.81	[4]149	45	654	142				
						58	2.99	.88	[4]207	63	908	162				
						59	2.82	.85	[4]195	59	855	164				
104	M.	May 24	51	.. [3]1	3.32	41	2.17	....	...	...	....	114	35.6	37.3	.. ..	No food.
						64	1.90	.92	[4]129	39	563	113				
						61	1.55	.85	[4]105	32	459	107				
						63	1.68	.96	[4]114	34	498	106				
						66	1.65	.89	[4]112	34	489	112				
						60	2.58	.88	[4]176	53	769	135				
						62	1.95	.82	[4]133	40	581	118				
105	M.	May 26	50.5	.. [3]2¾	3.37	40	2.21	....	...	...	....	119	36.1	37.8	.. ..	No food.
						63	1.85	.83	[4]130	39	560	129				
						63	2.12	.89	[4]150	45	647	128				
						58	2.33	.89	[4]164	49	707	127				
						63	1.90	.82	[4]134	40	578	123				
						61	2.02	.81	[4]142	42	612	126				
						61	2.41	.82	[4]170	50	733	130				
						60	2.04	.82	[4]144	43	621	132				

[1]The ages here given are at the beginning of the period of observation. For infants over 2 days old, the age is given to the nearest half day.

[2]Calculated from the weight of carbon dioxide produced during the period. The preliminary periods for all days are omitted in computing the minimum metabolism. See table 12, page 95.

[3]For the age from period to period, see table 10, p. 81.

[4]The average respiratory quotient obtained during the entire period of observation has been used in computing the heat-production,

*Minutes.

DISCUSSION OF RESULTS.

The data we have accumulated in this study of new-born infants permit a reasonably complete discussion of several phases of infant katabolism, particularly the character and the amount of the katabolism and the physiological needs of infants during the first week after birth.

CHARACTER OF THE KATABOLISM.

Though previous observations with adults and animals give us no reason to expect any particular kind of katabolism with new-born infants, except that which may be due to the character of the food-supply and possibly to muscular work as in severe crying, nevertheless since it is commonly believed that there is an excess of glycogen in the body of the new-born infant, it is necessary to examine carefully the character of the katabolism during the first week, if not, indeed, during the first hours of life. Such a study will give evidence as to the probable glycogen content of the body, or, more specifically, the availability of the glycogen content for supplying the needs of the body in the absence of the ingestion of food.

It was possible to determine the respiratory exchange of the infants by means of the respiration apparatus, and from these data to calculate the respiratory quotient for practically all of our observations. As has already been pointed out in our description of the technique, the greatest errors are liable to appear in the determination of the oxygen consumption, as this requires an exact knowledge of the temperature, humidity, and barometric pressure inside the chamber. Since this error may be minimized by measuring the oxygen consumption in long periods, it has been our custom to determine the oxygen consumption for the entire time that the infant was inside the chamber, subdividing the observations into periods upon the basis of the carbon-dioxide measurements. In certain observations these periods were made long enough to obtain fairly accurate respiratory quotients for the individual periods. This is particularly the case with the infants studied immediately after birth. Our data are therefore sufficiently extended to permit us to discuss the respiratory quotient of the new-born infant during the first week of life and particularly during the first 24 hours following birth.

RESPIRATORY QUOTIENT DURING THE FIRST 24 HOURS OF LIFE.

The greater part of our evidence in regard to the respiratory quotient during the first 24 hours of life was obtained in those observations which were specifically designed to study this question, namely, those in which the infants were observed almost immediately after birth. The periods were for the most part 1 hour long and therefore may reasonably be expected to give satisfactory determinations of the oxygen consumption. The results are given in abstract in table 10.

TABLE 10.—*Respiratory quotients of infants during early hours after birth.*

Subject No.	Sex.	Age at beginning of period.	Respiratory quotient.[1]	Carbon dioxide per hour.	Relative activity[2] estimated from kymograph records.	
					Obs. I.	Obs. II.
		h. *m.*		*gm.*		
80	M.	2 ..	0.75	2.14	B	B
		3 ..	.78	1.76	A	A
		4 ..	.90	3.99	D	C
		6 ..	[3].78	2.39	C	B
82	M.	3 ..	.76	1.28	A	A
		4 15	.78	1.60	B	B
		5 15	.83	1.75	B	B
		6 15	.80	1.77	C	B
83	M.	2 30	.80	2.06	A	A
		3 30	.90	2.21	A	A
		4 30	.83	2.22	B	B
		5 30	.83	2.20	C	C
		6 30	.85	2.24	B	B
		7 30	.79	2.39	D	D
		8 30	[.99]	3.55	E	E
84	F.	2 ..	.76	1.82	B	A
		3 ..	.83	1.81	A	A
		4 ..	.80	2.26	D	C
		5 ..	.86	3.09	F	D
		6 ..	.83	2.70	E	C
		7 ..	.75	2.02	C	B
		8 ..	.77	2.04	C	B
87	M.	1 30	.79	2.06	A	A
		2 45	[1.05]	2.71	D	C
		3 30	[.90]	3.78	F	D
		4 45	.81	2.42	B	B
		5 45	.76	2.18	A	A
		6 45	.84	2.27	C	B
		7 45	[.96]	3.70	E	D
93	M.	1 ..	.83	2.69	F	F
		2 ..	.77	1.86	D	C
		3 ..	.79	2.01	C	D
		4 ..	.87	2.69	E	E
		5 ..	.76	1.89	B	A
		6 ..	.77	1.89	A	A
		7 ..	.86	2.07	B	B
94	M.	1 15	.76	2.09	C	D
		2 15	.87	2.16	D	D
		3 15	.81	1.89	A	A
		4 15	.75	2.12	C	B
		5 15	[.96]	3.24	F	E
		6 15	.80	2.29	C	C
		7 15	.79	2.07	B	B
95	F.	1 15	.89	1.90	D	C
		2 15	.80	1.54	C	B
		3 15	.84	1.65	B	B
95	F.	4 15	0.83	1.71	B	B
		5 15	.70	1.41	A	A
		6 15	.84	1.58	B	B
		7 15	[.93]	2.09	E	D
96	F.	1 15	.93	1.87	F	D
		2 15	.85	1.75	D	C
		3 30	.91	1.65	A	A
		4 30	.89	1.95	C	B
		5 30	.80	1.75	A	A
		6 30	.86	1.88	B	B
		7 30	.86	2.09	E	E
97	F.	2 ..	.85	1.82	F	F
		3 ..	.84	1.75	E	E
		4 ..	.82	1.58	A	A
		5 ..	.87	1.61	B	B
		6 ..	.87	1.65	D	E
		7 ..	.86	1.84	C	D
		8 ..	.86	1.80	C	C
98	F.	2 ..	0.77	1.33	D	C
		3 ..	.90	1.93	F	D
		4 ..	.90	2.22	E	E
		5 ..	.74	1.50	C	B
		6 ..	.74	1.37	B	A
		7 ..	.79	1.38	A	A
		8 15	.85	1.50	B	A
99	M.	1 30	.79	2.09	B	B
		2 30	.83	1.78	A	A
		3 30	.93	3.09	D	C
		4 30	.90	2.33	C	B
		6 ..	.83	2.00	A	A
		7 ..	.89	2.81	D	D
		7 45	.87	3.25	E	E
100	M.	1 15	.90	3.47	D	E
		2 15	.98	3.43	D	F
		3 15	1.00	4.36	E	G
		4 15	.85	2.86	C	D
		5 15	.87	2.96	A	B
		6 15	.91	2.81	A	A
		7 15	.82	3.12	B	C
101	M.	1 15	.89	2.34	C	C
		2 15	1.00	2.69	F	E
		3 15	.94	2.73	E	E
		4 15	.82	1.90	B	B
		5 15	.81	1.87	A	A
		6 15	.88	2.27	D	D
		7 15	.86	2.29	D	D

[1]Duration of periods about 1 hour in practically all cases.

[2]The designations here used indicate only that the activity in one period is greater or less than in the other periods, the letter A being applied to the period of least activity in each case. The designations are not comparable for the different subjects.

[3]This quotient was obtained following an interval in which the cover of the chamber was removed to give the baby a small amount of sterile water and after a second preliminary period.

TABLE 10.—*Respiratory quotients of infants during early hours after birth*—Continued.

Subject No.	Sex.	Age at beginning of period.	Respiratory quotient.[1]	Carbon dioxide per hour.	Relative activity[2] estimated from kymograph records.	
					Obs. I.	Obs. II.
		h. m.		*gm.*		
102	M.	2 15	0.83	1.76	D	C
		3 15	.80	1.55	C	C
		4 15	.82	1.43	A	A
		5 15	.78	1.49	B	B
		6 15	.88	2.19	E	D
		7 30	.80	1.89	D	C
		8 30	.81	2.28	F	E
103	F.	1 15	.89	2.25	A	A
		2 15	.78	1.87	A	B
		3 15	.91	2.63	D	D
		4 15	.85	2.96	E	D
		5 15	.81	2.15	B	C
		6 15	.88	2.99	D	D
		7 15	.85	2.82	C	D
104	M.	1 45	0.92	1.90	D	C
		2 45	.85	1.55	B	A
		3 45	.96	1.68	A	A
		5 ..	.89	1.65	C	B
		6 ..	.88	2.58	E	D
		7 ..	.82	1.95	C	C
105	M.	3 15	.83	1.85	A	A
		4 30	.89	2.12	E	D
		5 30	.89	2.33	D	E
		6 30	.82	1.90	A	A
		7 30	.81	2.02	C	B
		8 30	.82	2.41	D	E
		9 30	.82	2.04	C	C

[1]Duration of periods about 1 hour in practically all cases.

[2]The designations here used indicate only that the activity in one period is greater or less than in the other periods, the letter A being applied to the period of least activity in each case. The designations are not comparable for the different subjects.

When we examine the individual quotients for each day, we find that at times there are great fluctuations, as, for instance, in the case of subject 83, in which there was an increase in the last period from 0.79 to 0.99. Since the infant had had no previous nourishment and was without food during the whole time that it lay in the respiration chamber, it is of course inconceivable that after $8\frac{1}{2}$ hours of fasting subsequent to birth there should have been this qualitative alteration to a metabolism which would be indicative of pure carbohydrate combustion. On several other days similar abnormal respiratory quotients are found, these being indicated in the table by brackets. These brackets are not used to differentiate sharply between the correct and incorrect quotients, but merely to point out the most strikingly defective quotients.

There may be two reasons for these defective quotients. In the first place, they may be due to excessive carbon-dioxide excretion, unaccompanied by a corresponding increase in the oxygen absorption, or they may be due to a defect in the measurement of the oxygen, particularly of the residual oxygen inside the chamber. If we examine the values given in this table for the total carbon-dioxide production, we find that at times there are very great increases. Thus, with infant No. 80, there was an increase of over 100 per cent in the carbon-dioxide production from the second to the third period of the observation, this being accompanied by an increase of 0.12 in the respiratory

quotient. With practically all of the quotients which are inclosed in brackets we find very great increases in the carbon-dioxide production over that of the preceding period; hence we may ascribe at least a portion of this change in the quotient to an excess carbon-dioxide excretion. It is not impossible that a certain amount of the carbon dioxide thus excreted may be due to actual over-ventilation of the lungs of the infant, produced by excessive crying; this can not, however, account for the entire increase.

For a partial explanation of these variations in the carbon-dioxide production, we may with profit examine the kymograph records accompanying each period. It is impracticable to publish all of the records obtained in this series of observations; accordingly two skilled observers have examined them independently and have indicated the relative activity by ascribing a letter to each individual period. This classification is not intended as a comparison of the activity of one infant with another, nor do the letters designate arbitrary degrees of muscular repose. They apply only to the activity of each infant by itself and show the muscular repose of the individual periods as related to that of the other periods, A being used to designate the greatest degree of muscular repose. If there are two periods in an observation when the muscular repose is of exactly the same degree, they are given the same letter. (See infant No. 82.) The estimations made by Observer I and Observer II never differ more than one unit in classification and usually they are identical. It will be seen that in practically all of the instances in which abnormally high quotients were found, there was a great increase in the activity as shown by the kymograph record. While a variation in the degree of muscular repose is not always accompanied by a variation in the respiratory quotient, nevertheless this is true in the majority of cases.

In view of these considerations, we must accept with reserve the respiratory quotients which do not lie within reasonable limits of the average quotient for the day. If the infant organism were surcharged with glycogen we would normally expect to find a high respiratory quotient shortly after birth, with a gradual decrease throughout the day. A critical examination of all of the values in table 10 shows a distinct, though slight, tendency for the quotient to fall off during the day; on the other hand, the initial quotients are not extremely high, being for the most part considerably less than 0.90. We may therefore properly conclude that while the quotients have a tendency to decrease as the period of inanition lengthens, since the quotients are rarely as high as 0.90, even when obvious technical errors are eliminated, we can not infer that the katabolism is chiefly that of carbohydrate during the observation period.

According to the table of Zuntz and Schumburg, a non-protein respiratory quotient of 0.90 corresponds to a combustion in which 66 per cent of the total energy is derived from carbohydrate and 34

per cent from fat. While with these infants we have not been able to secure a non-protein respiratory quotient, we may safely disregard this fact and assume that a quotient of 0.90 with these infants corresponds to a katabolism in which approximately two-thirds of the maintenance metabolism is derived from carbohydrate.

To obtain the average respiratory quotient for these infants on the first day of life, we may best examine the values given in table 11, in which all of the respiratory quotients on the first day have been brought together and averaged. We find that the average respiratory quotient for 74 infants on the first day of life was 0.80, a value materially lower than the quotient of 0.90 occasionally appearing in the first few hours of life. This value of 0.80 represents a fasting value not widely different from that observed during the first 24 hours with fasting man, a previous publication from this laboratory showing that the average respiratory quotient in 14 experiments with 10 men was 0.79 on the first day.[1]

[1]Benedict, Carnegie Inst. Wash. Pub. No. 77, 1907, p. 451.

TABLE 11.—*Respiratory quotients of infants during first 8 days after birth.*

[*Breast milk commencing.[1] ‡Breast milk sufficient.[1]]

Subject No.	Sex.	First day.		Second day.		Third day.		Fourth day.		Fifth day.		Sixth day.		Seventh day.		Eighth day.	
		Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.
		kg.		*kg.*		*kg.*		*kg.*		*kg.*		*kg.*		*kg.*		*kg.*	
[2]1	Male	....	....	....	....	3.13	0.65	....	....	2.90	0.63	....	....	....	....	2.73	0.65
2	Female	....	....	....	....	....	....	....	....	....	....	....	....	3.79	0.69	3.80	.70
3	Male	....	....	3.61	0.69	3.64	*.70	3.69	0.68	3.71	‡.84	....	....	....	....	....	....
4	Female	3.52	0.86	3.28	.70	3.27	.75	3.26	*.68	3.41	‡.89	3.40	0.80	....	....	....	....
[2]5	Male	3.82	.82	3.38	.71	....	....	....	....	....	....	....	....	....	....	....	....
6	Male	4.60	.90	4.36	.69	4.23	.72	4.25	*.69	4.38	‡.82	....	....	....	....	....	....
7	Male	....	....	....	....	....	....	....	....	....	....	....	....	3.90	.84	3.89	.87
8	Male	3.64	.77	3.37	.76	3.40	*.63	3.31	.72	....	....	....	....	....	....	....	....
9	Female	....	....	4.21	.75	4.04	*.77	....	....	....	....	....	....	....	....	....	....
10	Male	....	....	3.52	.67	3.37	?*.65	....	....	....	....	....	....	....	....	....	....
11	Male	4.08	.86	3.92	.72	3.77	*.66	....	....	....	....	....	....	4.00	.83	....	....
12	Female	....	....	....	....	....	....	4.17	.75	4.11	.73	4.17	.78	....	....	....	....
13	Female	....	....	3.37	.83	3.20	.77	3.19	*.84	....	....	....	....	....	....	....	....
14	Male	4.22	.79	3.95	.73	3.80	.75	3.71	.75	3.77	.80	....	....	....	....	....	....
15	Male	3.77	.80	3.74	.69	3.73	*.68	3.67	.72	3.63	.75	3.57	.73	....	....	3.80	.94
16	Female	4.11	.76	4.08	.76	3.91	.75	3.97	*.88	....	....	4.00	.90	....	....	....	....
17	Female	3.66	.76	3.43	.75	3.40	*.72	3.40	?‡.73	....	....	....	....	....	....	....	....
18	Male	3.18	.81	3.03	.65	2.91	*.60	2.92	.67	2.86	.72	....	....	2.84	.78	....	....
19	Male	3.47	.82	3.52	.84	....	....	3.37	.86	3.29	.85	3.35	‡.89	....	....	....	....
20	Female	3.74	.75	3.60	.77	3.54	.77	3.54	*.82	3.62	‡.85	....	....	....	....	....	....
21	Female	3.05	.72	2.92	.72	2.98	*.78	3.02	‡.81	3.01	.81	....	....	....	....	....	....
22	Female	....	....	2.81	.71	2.72	.71	2.72	*.75	2.89	‡.87	2.86	.88	2.86	.90	....	....
23	Female	....	....	3.63	.79	3.60	.83	3.46	*.76	3.46	.80	3.52	‡.80	3.52	.88	....	....
[2]24	Male	2.35	.77	....	....	....	....	....	....	....	....	....	....	....	....	....	....
25	Male	3.37	.79	3.33	.76	3.35	.78	3.26	*.76	3.37	‡.87	3.50	.92	....	....	3.57	.94
26	Female	....	....	....	....	....	....	3.40	.78	3.45	.84	3.52	.84	....	....	....	....
27	Male	3.83	.76	3.74	.72	3.74	.69	3.52	*.68	3.63	‡.76	....	....	3.77	.86	3.83	.88
28	Female	....	....	3.49	.77	3.60	*.70	....	....	....	....	....	....	....	....	....	....
29	Female	3.63	.82	3.52	.78	3.32	.73	3.26	*.83	....	....	3.37	.80	3.46	.81	....	....
30	Male	....	....	3.43	.71	3.29	*.71	3.26	.72	....	....	3.32	.80	3.32	.81	....	....

[1]The interrogation points in some of the columns apply to the * or ‡, respectively, and not to the figures. A clear gain in weight was the criterion for placing the designation (‡). In the case of certain infants three or more days old at the first observation, no designations were used in the belief that the breast-milk was already established. Also, when there were more than 36 hours between observations, either of the designations may have been omitted. If there was no gain in weight, even if breast-milk was recorded, it evidently was not sufficient; the designation (‡) was therefore omitted.

[2]Pathological. See table 9.

TABLE 11.—*Respiratory quotients of infants during first 8 days after birth*—Continued.

[*Breast milk commencing.[1] ‡Breast milk sufficient.[1]]

Subject No.	Sex.	First day.		Second day.		Third day.		Fourth day.		Fifth day.		Sixth day.		Seventh day.		Eighth day.	
		Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.	Body-weight.	Respiratory quotient.
		kg.		*kg.*		*kg.*		*kg.*		*kg.*		*kg.*		*kg.*		*kg.*	
31	Male	....	....	....	....	....	....	....	....	3.56	0.81	....	....	....	....	....	....
32	Male	3.49	0.65	....	....	....	....	3.35	0.63	3.41	‡.85	....	....	....	....	....	....
33	Male	....	....	....	....	3.66	*0.83	3.74	?‡.83	3.70	.64	3.76	0.69	3.71	0.76	3.78	0.69
34	Female	....	....	....	....	2.90	*.74	3.00	‡.74	3.08	.90	3.16	.85	....	....	....	....
35	Female	....	....	4.41	0.71	4.33	.73	....	....	4.32	.77	4.29	.71	4.35	.82	4.38	.74
36	Male	3.33	.75	....	....	....	....	....	....	....	....	....	....	....	....	....	....
37	Female	2.49	.80	....	....	2.39	*.75	2.39	.70	2.44	‡.73	....	....	....	....	....	....
38	Female	4.20	.69	3.90	.79	3.71	*.66	....	....	....	....	....	....	....	....	....	....
39	Female	2.95	.79	2.71	.78	2.61	*.70	2.72	‡.75	2.78	.90	2.85	.83	....	....	....	....
40	Female	....	....	2.86	.76	2.78	.84	2.75	?*.82	....	....	2.81	.77	....	....	....	....
[2]41	Male	3.91	.95	....	....	....	....	....	....	....	....	....	....	....	....	....	....
42	Female	3.94	.72	3.87	.69	3.96	‡.80	4.03	.89	4.05	.89	....	....	....	....	....	....
43	Female	....	....	3.71	.74	3.62	*.75	....	....	....	....	....	....	....	....	....	....
44	Female	3.57	.79	3.34	.82	3.24	.75	....	....	3.18	.74	....	....	....	....	....	....
45	Female	2.66	.83	2.46	.74	2.49	*.74	....	....	....	....	....	....	....	....	....	....
46	Male	3.83	.74	3.59	.80	....	....	3.39	.72	3.42	‡.70	3.46	.84	3.60	.82	....	....
47	Male	3.51	.81	3.32	.68	3.16	*.78	3.22	‡.75	3.26	.74	3.30	.80	....	....	....	....
48	Female	4.55	.76	4.42	.75	4.37	*.67	4.39	.73	4.51	‡.79	4.52	.82	....	....	4.59	.83
49	Female	2.92	.88	2.78	*.75	2.72	.68	2.72	.78	2.75	?‡.79	....	....	....	....	....	....
50	Female	....	....	2.75	.76	....	....	....	....	....	....	....	....	....	....	....	....
51	Male	3.82	.73	3.68	.71	3.64	*.71	3.84	‡.80	3.84	.85	....	....	....	....	....	....
52	Female	....	....	3.46	.82	3.61	*.75	3.59	.71	3.56	.73	....	....	....	....	....	....
53	Male	....	....	3.13	.90	2.87	.76	....	....	....	....	....	....	....	....	....	....
54	Male	3.38	.83	3.31	.81	3.32	*.72	3.20	.76	....	....	....	....	....	....	....	....
55	Male	3.45	.76	....	....	....	....	....	....	....	....	....	....	....	....	....	....
56	Male	....	....	....	....	....	....	3.19	.73	3.19	.81	3.19	.85	3.13	.88	....	....
57	Male	3.90	.69	3.59	.78	3.55	*.71	....	....	3.69	.80	3.70	.83	....	....	....	....
58	Female	3.06	.76	2.96	.74	....	....	2.96	.78	....	....	....	....	....	....	....	....
59	Female	....	....	3.62	.75	3.57	.71	....	....	....	....	3.66	.81	....	....	....	....
60	Male	....	....	3.81	.74	....	....	....	....	3.60	.71	....	....	....	....	....	....
61	Male	3.26	.80	2.75	.73	2.69	.77	....	....	....	....	....	....	....	....	....	....
62	Male	3.36	.78	3.22	.78	3.27	*.67	3.27	.72	3.26	.82	....	....	....	....	....	....
63	Female	....	....	2.50	.68	2.36	.74	2.37	.71	2.32	*.74	....	....	....	....	....	....
64	Female	3.37	.82	3.00	.70	2.90	.68	....	....	3.26	.78	....	....	....	....	....	....
65	Female	2.61	.77	2.50	.70	2.52	*.72	2.64	‡.77	....	....	....	....	....	....	....	....
66	Male	3.19	.76	3.06	.79	3.08	*.77	3.09	.67	3.15	‡.87	....	....	....	....	....	....

67	Male	4.99	.87	4.62	.81	....	....	4.86	?*.77	4.85	.82	....	....	....	....	....	....
68	Male	....	....	2.31	.72	2.18	*.76	2.13	.67	2.11	.68	....	....	....	....	....	....
69	Male	3.52	.79	3.35	.68	3.37	*.76	....	....	....	....	....	....	....	....	....	....
70	Male	....	....	3.66	.74	3.63	*.68	3.46	.79	....	....	....	....	....	....	....	....
71	Male	....	....	....	....	3.92	.72	3.94	?‡.83	4.00	.81	....	....	....	....	....	....
72	Male	....	....	....	....	3.29	.68	....	....	....	....	....	....	....	....	....	....
73	Male	3.63	.80	3.44	.73	3.30	.81	3.40	‡.82	....	....	....	....	....	....	....	....
74	Male	3.58	.74	3.63	.75	....	....	....	....	....	....	....	....	....	....	....	....
75	Male	....	....	2.65	*.70	2.64	.70	2.69	‡.75	....	....	....	....	....	....	....	....
76	Male	3.16	.76	....	....	....	....	....	....	....	....	....	....	....	....	....	....
77	Female	3.83	.89	....	....	....	....	....	....	....	....	....	....	....	....	....	....
78	Male	2.48	.68	....	....	....	....	....	....	....	....	....	....	....	....	....	....
79	Female	4.14	.78	3.97	.68	3.89	*.76	3.83	.76	....	....	....	....	....	....	....	....
80	Male	3.47	.81	....	....	....	....	3.37	?*.75	....	....	....	....	....	....	....	....
81	Female	3.29	.77	....	....	....	....	....	....	....	....	....	....	....	....	....	....
82	Male	2.74	.79	....	....	....	....	....	....	....	....	....	....	....	....	....	....
83	Male	3.73	.86	3.47	.72	....	....	....	....	....	....	....	....	3.74	.76	....	....
84	Female	4.11	.80	....	....	3.74	?*.76	....	....	....	....	....	....	....	....	....	....
85	Male	3.52	.82	....	....	....	....	....	....	....	....	....	....	....	....	....	....
86	Female	3.32	.75	....	....	....	....	3.06	.70	....	....	....	....	....	....	....	....
87	Male	3.94	.87	3.72	.70	....	....	....	....	....	....	....	....	....	....	....	....
88	Female	2.62	.75	....	....	....	....	....	....	....	....	....	....	....	....	....	....
89	Male	3.24	.74	3.12	.76	3.08	*.75	3.18	‡.78	....	....	....	....	3.16	.76	....	....
90	Male	3.15	.78	3.07	.73	2.92	*.76	....	....	....	....	....	....	....	....	....	....
91	Female	3.33	.79	3.21	*.76	....	....	....	....	....	....	....	....	....	....	....	....
92	Female	3.78	.86	....	....	3.52	.82	....	....	....	....	....	....	....	....	....	....
93	Male	3.53	.81	....	....	....	....	....	....	....	....	....	....	....	....	....	....
94	Male	3.20	.82	....	....	2.89	.77	....	....	....	....	....	....	....	....	....	....
95	Female	2.84	.83	....	....	....	....	....	....	....	....	....	....	....	....	....	....
96	Female	3.23	.87	....	....	....	....	....	....	....	....	....	....	....	....	....	....
97	Female	2.82	.85	....	....	....	....	....	....	....	....	....	....	....	....	....	....
98	Female	2.86	.82	....	....	....	....	....	....	....	....	....	....	....	....	....	....
99	Male	3.58	.87	....	....	....	....	....	....	....	....	....	....	....	....	....	....
100	Male	4.65	.91	....	....	....	....	....	....	....	....	....	....	....	....	....	....
101	Male	3.88	.89	....	....	....	....	....	....	....	....	....	....	....	....	....	....
102	Male	2.84	.82	....	....	....	....	....	....	....	....	....	....	....	....	....	....
103	Female	3.29	.86	....	....	....	....	....	....	....	....	....	....	....	....	....	....
104	Male	3.32	.88	....	....	....	....	....	....	....	....	....	....	....	....	....	....
105	Male	3.37	.84	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average		3.48	**0.80**	3.41	**0.74**	3.32	**0.73**	3.34	**0.75**	3.43	**0.79**	3.51	**0.82**	3.54	**0.81**	3.82	**0.80**
Number of subjects		....	74	....	64	....	62	....	51	....	41	....	22	....	15	....	9

[1]The interrogation points in some of the columns apply to the * or ‡, respectively, and not to the figures. A clear gain in weight was the criterion for placing the designation (‡). In the case of certain infants three or more days old at the first observation, no designations were used in the belief that the breast-milk was already established. Also, when there were more than 36 hours between observations, either of the designations may have been omitted. If there was no gain in weight, even if breast-milk was recorded, it evidently was not sufficient; the designation (‡) was therefore omitted.

[2]Pathological. See table 9.

Some of the infants obtained a certain amount of colostrum prior to the measurement of the metabolism; they were therefore not in all cases in the post-absorptive condition when the metabolism was measured. Most of the infants, however, were in the post-absorptive condition during the observations and the average value obtained for the respiratory quotient, *i. e.*, 0.80, may very properly be compared with the average respiratory quotient of 0.79 which was previously cited for 10 men on the first day of their fast. This comparison of itself would therefore lead one to conclude that there was not an excessive deposit of glycogen in the bodies of new-born children, for according to the table of Zuntz and Schumburg, a respiratory quotient of 0.79 corresponds to a metabolism in which approximately one-third of the energy comes from carbohydrate and two-thirds from fat.

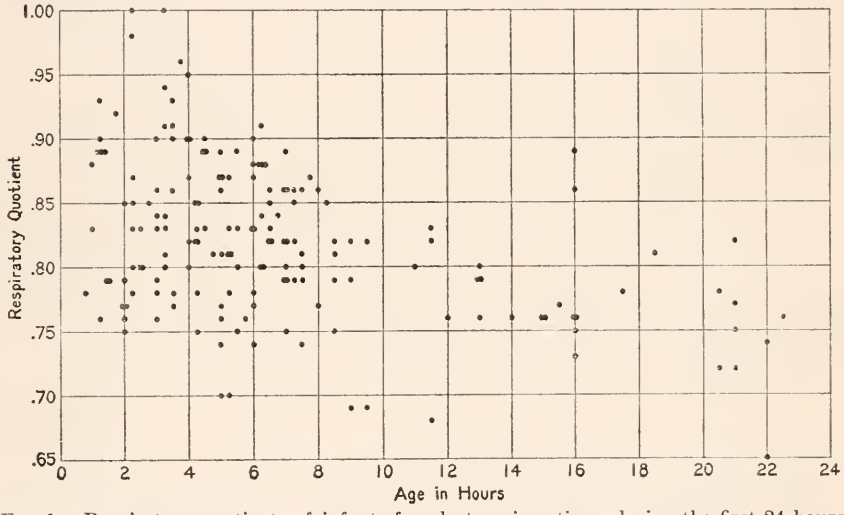


FIG. 1.—Respiratory quotients of infants found at various times during the first 24 hours.

The trend of the respiratory quotient during the first 24 hours after birth may perhaps best be shown graphically. We have therefore plotted from table 10 all of the individual respiratory quotients obtained during the first day, with the exception of the bracketed values, and have supplemented these with the average values from table 11 for the infants whose respiratory exchange was not studied in short periods in the first 24 hours. The values on this chart (see fig. 1) show that during the first 24 hours of life there was a slight, though definitely observable, decrease in the respiratory quotient as time progressed. Although this was not sufficiently characteristic to justify its representation by a curve, when we compare the quotients above and below 0.80, we find that up to the eighth hour the greater number lie above 0.80, while subsequent to the tenth hour the larger proportion lie below this value.

RESPIRATORY QUOTIENT DURING THE FIRST WEEK OF LIFE.

Table 11 also shows the respiratory quotients obtained for each day up to the eighth day inclusive, the interval between successive daily quotients being approximately 24 hours. The time when the breast-milk appeared is designated by an asterisk (*) and when the milk was sufficient in amount by the designation (‡). Evidence that the infant was clearly gaining weight was the criterion used in placing the designation (‡). In the case of certain infants who were 3 or more days old when the first observations were made, no designations have been placed on the respiratory quotients, since apparently the breast-milk was already established. Furthermore, when there was an interval of more than 36 hours between observations, either of the designations may have been omitted. When there was no gain in weight, even if breast-milk was recorded, it evidently was not sufficient; the designation (‡) was therefore omitted. All weights are without clothing.

If we study the variations in the respiratory quotient found with the new-born infants during the first week of life as shown in table 11, we note a distinct tendency for the quotient to decrease after the first day, reaching the lowest average of 0.73 on the third day. Thereafter there was a tendency for the respiratory quotient to increase and on the last 3 days the average was not far from 0.81. The average value found with 74 infants on the first day was 0.80; with 64 infants on the second day, 0.74; with 62 infants on the third day, 0.73; with 51 infants on the fourth day, 0.75; with 41 infants on the fifth day, 0.79; with 22 infants on the sixth day, 0.82; with 15 infants on the seventh day, 0.81; and with 9 infants on the eighth day, 0.80. It is quite obvious that some factor entering into the nourishment of the infant produced a change in the metabolism which raised the average respiratory quotient from a minimum of 0.73 on the third day of life to 0.81 at the end of the first week.

According to the table of Zuntz and Schumburg, if we assume that these are non-protein respiratory quotients, 0.73 would correspond to a metabolism in which somewhat less than 10 per cent of the energy was derived from carbohydrate and the remainder from fat, while a quotient of 0.81 would correspond to a metabolism in which one-third of the energy was the result of a carbohydrate combustion and two-thirds was derived from a fat combustion. It is thus obvious that the infant between the third and seventh days secured a supply of carbohydrate which was not drawn from the body-material. This could be derived only from the nourishment taken, usually in the mother's milk.

The profound influence of the mother's milk upon the character of the katabolism is shown by the fact that the time when the milk began to appear in the mother's breasts, as indicated by the asterisk (*), almost invariably coincides with the increase in the respiratory quotient. On the first day of life the infant is subsisting upon the moder-

ate amount of glycogen in the body at birth. On the second, third, and fourth days the colostrum is entirely insufficient to supply the needed energy; on the fifth day the milk flow is usually established and subsequently the respiratory quotient is not far from 0.81, indicating a katabolism in which somewhat over one-third of the energy is derived from carbohydrate. This quotient is not far from that found with normal individuals. Thus, in the study made by Benedict, Emmes, Roth, and Smith,[1] in which 157 individuals (89 men and 68 women) subsisting upon a mixed diet were studied, the post-absorptive katabolism showed a respiratory quotient of 0.81. Comparing this average value with the respiratory quotients found with the new-born infants, we may properly infer that the infant at birth has not an excessive supply of glycogen in the tissues. We may further conclude that the glycogen supply is somewhat rapidly exhausted on the first day and it is not until the supply of milk from the mother's breasts is established that we find a respiratory quotient indicating a considerable combustion of carbohydrate.

Further light is thrown upon this subject by a consideration of the changes in body-weight during the first week. While it is practically a routine in all hospitals to record the birth-weight of infants, it is a well-known fact that in many instances the record may represent the weight either before or after the meconium is passed, and that the true physiological weight is not known. It is rarely that weights are obtained from day to day, so that comparisons can be made and the curve studied. As was stated in a previous section, there is at first a distinct normal loss in body-weight with a subsequent rise; our observations, the results of which are given in table 11, have in consequence a peculiar significance in this connection.

The average body-weight for the first 7 days of life was as follows: On the first day, with 74 subjects, 3.48 kg.; on the second day, with 64 subjects, 3.41 kg.; on the third day, with 62 subjects, 3.32 kg.; on the fourth day, with 51 subjects, 3.34 kg.; on the fifth day, with 41 subjects, 3.43 kg.; on the sixth day, with 22 subjects, 3.51 kg.; and on the seventh day, with 15 subjects, 3.54 kg. These figures are not wholly comparable, as the weights were not obtained for the same individuals during the whole period. Computations were made, however, of the body-weight of 44 infants for both the first and second days; these show that the body-weight for the first day was 3.61 kg. and for the second day, 3.44 kg. There was therefore a loss of weight during the first day of 170 grams. It is also clear that there was a further distinct loss on the second and third days, which was followed by an increase in the later days. It should be stated that during the first few days the small amount of food taken would have relatively but little effect upon the body-weight, although the sterile water, which was

[1]Benedict, Emmes, Roth, and Smith, Journ. Biol. Chem., 1914, 18, p. 139.

frequently given, would naturally tend to increase the weight somewhat. On the other hand, the 170 grams of body-weight lost on the first day can not in any way be considered as being a loss of either flesh or fat, but, as was pointed out in a preceding section, was doubtless due in large part to a loss of water from the body.

It was noted that the establishment of the flow of milk was, as a rule, coincident with an increase in the respiratory quotient. Here again we find in considering the records of the body-weight that this factor also tends to increase at the time that the milk-flow is established. In general, therefore, after the first day the infant loses weight while the food-supply is insufficient, particularly in carbohydrate, and increases in weight when the milk-supply is established.

INFLUENCE OF BODY-WEIGHT UPON THE RESPIRATORY QUOTIENT.

Since it was possible that the store of glycogen in the body of the infant might vary considerably with variations in the size and nourishment, the respiratory quotients were compared with the body-weights of the infants. This comparison is shown in figure 2, in which the actual body-weights of the infants during the first 24 hours are plotted

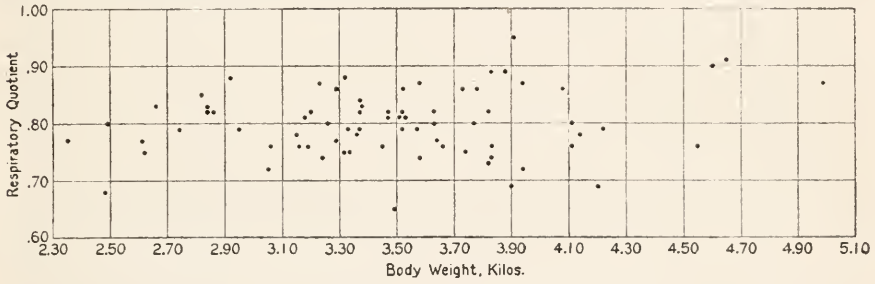


FIG. 2.—Respiratory quotient of infants in first 24 hours referred to total body-weight.

against the respiratory quotients obtained for the same period. A careful examination of the chart shows no tendency toward a variation in the average quotient as the weight varies. We must therefore infer that the respiratory quotient is independent of the weight.

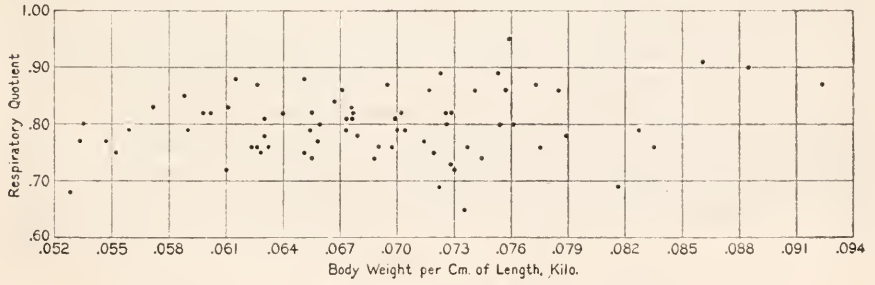


FIG. 3.—Respiratory quotient of infants in first 24 hours referred to body-weight per unit of length of infant.

Since, however, infants of approximately the same weight but of varying length may differ in the degree of nourishment, the relationship between the weight and the length of the infants may be of significance in this connection; the weight per unit of length may thus be a better basis for comparison than the actual weight. The values have therefore been compared on this basis in figure 3, in which the respiratory quotients have been plotted against the weight per unit of length. Using the average respiratory quotient of 0.80 as a base-line, we find no distinct tendency toward a grouping of the values. Such differences as may be apparent are not sufficiently striking to allow us to make any other deduction than that the respiratory quotient appears to be absolutely independent of the weight and the state of nutrition. Unfortunately our hospital and other data do not provide definite information regarding the degree of nutrition of the mothers. No relationship can therefore be established between the nature of the katabolism of the new-born infant in the first few hours after birth and the state of nutrition of the mother.

GENERAL CONCLUSIONS AS TO CHARACTER OF KATABOLISM OF NEW-BORN INFANTS.

From the results obtained in our experiments we are unable to verify Hasselbalch's conclusion that the metabolism of the new-born infant in the first few hours is chiefly of carbohydrate material. It is true that in practically none of our observations were we able to secure data so soon after birth as did Hasselbalch. Thus, while he frequently records observations beginning 30 to 45 minutes after birth and, indeed, in one instance 15 minutes after birth, our values were rarely obtained in observations less than an hour after birth, and for the most part they were 2 or more hours after birth. On the other hand, the time relations in our observations are fully comparable to the fragmentary data published by Bailey and Murlin, since in only two of their cases were observations made as early as 6 hours after birth, and there was but one period in each case.

If we examine the data published by Hasselbalch, particularly the values given in table 2 (see page 21), we find that a great decrease in the respiratory quotient is accompanied by a very large decrease in the total katabolism as indicated by the carbon-dioxide production. Thus in his observation No. 17 the carbon-dioxide production per kilogram per hour was 344 c.c. and the respiratory quotient was 0.933, while the next period showed a carbon-dioxide production per kilogram per hour of only 275 c.c. and a respiratory quotient of 0.854. A similar relationship between the variations in the metabolism as indicated by

the carbon-dioxide production and the respiratory quotient is shown in observations Nos. 13–14 and 19–20.

It will be remembered that in our consideration of the values in table 10 (see page 81), a like increase in the metabolism was found to accompany the abnormal increase in the respiratory quotient and that the conclusion was drawn that this increase was in part due to the muscular activity of the infant, and specifically to the excess carbon-dioxide produced in crying. The notes accompanying Hasselbalch's protocols specify that the infant was not crying; nevertheless we know too little at present regarding the ventilation of the lungs of new-born infants not to assume that there may certainly have been a distinctly excessive ventilation, with an accompanying increase in the carbon-dioxide excretion. We have here, then, an actual increase in the katabolism of considerable magnitude, with the high probability of there being somewhat more carbon dioxide produced than oxygen consumed, the difference being sufficient to cause a corresponding variation in the respiratory quotient.

The fact that in a large number of our observations of long duration these abnormally high quotients appear not only in the first hours, but, later, lends considerable strength to this supposition. We are inclined to believe, therefore, that Hasselbalch's conclusion that the higher respiratory quotients are obtained in those observations which are nearest to the birth is due not to the larger proportion of the glycogen taking part in the combustion, but to an increase in the carbon-dioxide excretion, owing to a disturbance in the mechanics of respiration.

On the first day of life there is a gradual decrease in the respiratory quotient which is fully comparable to that experienced with any fasting organism in which the initial supply of glycogen is fairly liberal. On the other hand, the quotients found shortly after birth and the level to which they fall on the first day are not such as to justify the conclusion that there is an excessive glycogen storage in the body of the new-born infant. On the second and subsequent days the respiratory quotients decrease, indicating a somewhat rapid depletion of glycogen until the quotient of 0.73 is reached, this being similar to the metabolism of fasting animals. When the milk-flow is fully established, and the body is in consequence supplied more liberally with carbohydrate material, the average respiratory quotient increases until at the end of the first week it is 0.81.

No obvious relationship between the respiratory quotient and the size and condition of nourishment can be found from the data obtained. As information is lacking in regard to the degree of nourishment of the mothers, no study can be made of the relationship between the respiratory quotient and this factor.

BASAL KATABOLISM.

Direct measurements of the heat-production are only possible with extremely complicated and expensive calorimetric devices. Thus far no one has successfully completed such measurements with infants save Howland.[1] As it was impracticable to make direct measurements of the heat-output in our study of the metabolism of new-born infants, we were obliged to content ourselves with the indirect method of computing the energy from the carbon-dioxide elimination and the oxygen consumption. Fortunately the interesting research of Howland has shown that this method of determining the energy output gives results of a high degree of accuracy. On the other hand, it is impossible to compare the results obtained with an infant in half-hour or hour periods at different times of the day unless there was like extraneous muscular activity in the periods compared. It is much less possible to compare the results obtained with different infants without an assurance of complete muscular repose during the time of the observations. From the beginning of our research we have laid emphasis upon graphic records of the degree of muscular repose, and we are glad to note that this is now bearing fruit in that practically all experimenters are to-day of one mind regarding the absolute necessity of using periods of minimum activity for comparison.

Even in so extended a series of observations as is reported here, we were not able with all of the infants to secure periods of absolutely minimum muscular activity. A critical examination of all the kymograph records was made independently by two skilled observers and periods of practically minimum activity were selected wherever it was possible. In the selection of these periods, however, actual minimum heat values were sought; a careful inspection was therefore made of the heat-production as computed from the carbon dioxide observed. Minimum values were secured for 94 out of the 105 infants. These results have been averaged and are given in table 12. It was rarely necessary to make use of a minimum value obtained from but one period in the series of observations with an infant. These periods of minimum activity and heat-production may be found with comparative ease by referring to the statistical table (see pages 46 to 79).

[1]Howland, Proc. Soc. Exp. Biol. and Med., 1911, **8**, p. 63; Hoppe-Seyler's Zeitschr. f. Physiol. Chem., 1911, **74**, p. 1; Trans. 15th Int. Congress on Hygiene and Demography, Washington, 1913, **2**, p. 438.

TABLE 12.—*Minimum heat-production of new-born infants.*

Subject No.	Sex.	Body-weight without clothing.	Length.	Age.	Average rectal temperature.		Pulse-rate.	Heat produced (computed) per 24 hours.			
					°Cent.	°Fahr.		Total.	Per kilogram.	Per square meter (Lissauer, $10.3\sqrt[3]{W^2}$). Total.	Per square meter (Lissauer, $10.3\sqrt[3]{W^2}$). Per centimeter of length.[1]
		kg.	*cm.*					*cal.*	*cal.*	*cal.*	*cal.*
2	F.	3.80	53	6½ days	36.8	98.2	99	152	40	606	11.4
3	M.	3.63	52	2½ days	37.0	98.6	97	166	46	685	13.2
4	F.	3.28	46.5	2 days	37.2	99.0	105	139	43	612	13.2
5	M.	3.82	52.5	7 hrs.	36.9	98.4	112	137	36	544	....
6	M.	4.32	52	3½ days	37.0	98.6	116	191	44	697	13.4
8	M.	3.48	51	2 days	36.8	98.3	117	160	45	673	13.2
9	F.	4.04	51	2 days	37.3	99.2	109	178	44	677	13.3
10	M.	3.45	52	2 days	36.8	98.2	116	162	48	694	13.3
12	F.	4.17	52.5	5 days	37.0	98.6	112	171	41	639	12.2
13	F.	3.25	50	2 days	37.1	98.7	113	138	43	612	12.2
15	M.	3.64	50	4 days	37.0	98.6	122	162	44	665	13.3
16	F.	4.03	53	2½ days	37.1	98.8	113	175	44	670	12.6
17	F.	3.66	52.5	15 hrs.	36.8	98.3	118	174	48	713	....
18	M.	2.84	50.5	7 days	36.6	97.9	105	108	38	519	10.3
19	M.	3.50	53	1½ days	36.9	98.5	114	155	44	653	12.3
20	F.	3.54	52	3½ days	36.8	98.3	110	153	43	638	12.3
21	F.	2.92	50	2 days	36.9	98.4	121	136	47	645	12.9
22	F.	2.72	49	2½ days	36.8	98.2	114	128	47	635	13.0
25	M.	3.32	51.5	4 days	36.9	98.5	123	158	47	686	13.3
26	F.	3.46	50	5 days	37.2	98.9	113	151	44	645	12.9
27	M.	3.58	52	4 days	37.1	98.8	111	169	48	703	13.5
29	F.	3.37	50	2½ days	37.4	99.3	112	150	45	652	13.0
30	M.	3.33	51	2 days	37.1	98.7	114	144	43	623	12.2
31	M.	3.56	53.5	4 days	37.1	98.7	117	158	45	662	12.4
32	M.	3.42	47.5	2½ days	36.9	98.5	116	140	41	604	12.7
33	M.	3.73	52	5 days	37.1	98.7	129	153	41	617	11.9
34	F.	2.90	50.5	2 days	37.2	98.9	115	134	47	638	12.6
35	F.	4.33	54	4 days	37.2	98.9	109	175	41	640	11.9
36	M.	3.33	53	21 hrs.	37.6	99.6	129	154	46	670	....
37	F.	2.49	46.5	13 hrs.	36.8	98.3	119	99	40	522	....
38	F.	3.90	51.5	1½ days	37.4	99.3	127	156	40	610	11.8
39	F.	2.95	50	9 hrs.	36.5	97.7	105	113	38	533	....
40	F.	2.78	49.5	4½ days	37.4	99.4	111	134	48	655	13.2
42	F.	3.95	54	3 days	37.2	98.9	113	176	45	684	12.7
43	F.	3.62	50	2 days	37.6	99.6	119	165	46	682	13.6
44	F.	3.57	51	2 hrs.	36.9	98.4	103	136	38	567	....
45	F.	2.56	46.5	1 day	36.6	97.9	110	107	43	558	....
46	M.	3.83	51.5	5 hrs.	37.2	99.0	126	152	40	603	....
47	M.	3.51	52	5 hrs.	37.5	99.5	107	143	41	601	....
48	F.	4.52	54.5	6 days	36.9	98.4	132	188	42	667	12.2
49	F.	2.75	47.5	4 days	36.9	98.5	114	130	47	638	13.4
50	F.	2.75	48.5	1 day	36.4	97.6	89?	142	52	700	....
51	M.	3.73	52.5	2 days	36.9	98.5	96	154	42	623	11.9
52	F.	3.54	50	2½ days	37.2	99.0	114	138	39	579	11.6
53	M.	2.87	47.5	2 days	37.7	99.9	126	143	50	684	14.4
54	M.	3.31	50	1½ days	37.1	98.7	106	129	39	563	11.3
55	M.	3.45	50	16 hrs.	36.9	98.4	124	151	44	641	....
56	M.	3.19	51.5	4 days	36.9	98.4	121	150	47	669	13.0
57	M.	3.75	54	22 hrs.	36.9	98.5	105	153	40	611	....

[1]Computed only for infants of ages between 1½ and 6 days inclusive. See fig. 10, p. 107.

TABLE 12.—*Minimum heat-production of new-born infants*—Continued.

Subject No.	Sex.	Body-weight without clothing.	Length.	Age.	Average rectal temperature.		Pulse-rate.	Heat produced (computed) per 24 hours.			
					°Cent.	°Fahr.		Total.	Per kilogram.	Per square meter (Lissauer $10.3\sqrt[3]{W^2}$). Total.	Per square meter (Lissauer $10.3\sqrt[3]{W^2}$). Per centimeter of length.[1]
		kg.	*cm.*					*cal.*	*cal.*	*cal.*	*cal.*
58	F.	3.01	49	1 day	37.2	98.9	111	139	46	647	....
59	F.	3.60	52	1½ days	37.1	98.8	112	150	42	621	11.9
60	M.	3.60	52	4½ days	37.0	98.6	117	149	42	617	11.9
61	M.	3.26	49.5	2½ hrs.	36.6	97.8	121	123	38	542	....
62	M.	3.30	49.5	3 days	36.8	98.3	116	134	41	588	11.9
63	F.	2.37	47.5	3 days	37.2	98.9	125	109	46	596	12.5
64	F.	3.37	48	7 hrs.	36.7	98.1	98	128	38	552	....
65	F.	2.63	49	2 days	36.8	98.2	116	127	48	644	13.1
66	M.	3.19	51	14 hrs.	36.3	97.4	103	122	38	543	....
67	M.	4.74	54	3 days	37.1	98.7	122	193	41	669	12.4
68	M.	2.12	46	4 days	36.8	98.3	113	103	48	604	13.1
69	M.	3.44	50	19 hrs.	36.9	98.5	110	142	42	609	....
70	M.	3.56	51	2 days	36.9	98.5	109	153	43	640	12.5
71	M.	3.96	53.5	3 days	36.8	98.2	106	172	44	667	12.5
72	M.	3.29	50.5	2½ days	36.7	98.0	110	157	48	687	13.6
73	M.	3.63	50	7 hrs.	36.8	98.2	106	164	45	673	....
74	M.	3.63	52	2 days	36.8	98.3	94	156	43	640	12.3
75	M.	2.65	47.5	1½ days	36.6	97.9	100	132	50	664	14.0
76	M.	3.16	50	13 hrs.	36.7	98.0	101	137	44	618	....
78	M.	2.48	47	12 hrs.	36.4	97.6	101	109	44	577	....
79	F.	4.14	52.5	4 hrs.	36.9	98.4	116	153	37	575	....
80	M.	3.47	51.5	3 hrs.	36.4	97.6	109	128	37	542	....
81	F.	3.29	50	4 hrs.	36.9	98.4	114	167	51	732	....
82	M.	2.74	49	3 hrs.	36.4	97.6	101	95	35	470	....
83	M.	3.73	52	3 hrs.	37.2	99.0	131	148	40	597	....
84	F.	4.11	54	2½ hrs.	36.5	97.7	109	133	32	504	....
85	M.	3.52	52	9 hrs.	36.8	98.2	109	144	41	605	....
86	F.	3.32	51	6 hrs.	36.6	97.8	103	120	36	524	....
87	M.	3.94	51	3½ hrs.	37.3	99.2	118	146	37	567	....
88	F.	2.62	47.5	9 hrs.	36.8	98.3	96	122	47	623	....
89	M.	3.24	49.5	8 hrs.	36.7	98.0	107	124	38	549	....
90	M.	3.00	50	2½ days	36.8	98.2	86	138	46	641	12.8
91	F.	3.33	49.5	13 hrs.	37.4	99.4	113	140	42	609	....
92	F.	3.78	51	4 hrs.	36.6	97.8	112	157	42	628	....
93	M.	3.53	50.5	4 hrs.	36.8	98.2	127	136	39	573	....
94	M.	3.20	50	3½ hrs.	36.8	98.2	117	136	43	607	....
95	F.	2.84	46.5	5½ hrs.	36.2	97.1	123	100	35	483	....
96	F.	3.23	51.5	3½ hrs.	36.6	97.8	99	113	35	502	....
97	F.	2.82	48	4½ hrs.	36.1	96.9	113	112	40	542	....
98	F.	2.86	47.5	5 hrs.	36.2	97.1	102	98	35	471	....
99	M.	3.58	51.5	2½ hrs.	36.9	98.4	103	122	34	508	....
100	M.	4.65	54	6½ hrs.	37.1	98.8	130	186	40	648	....
101	M.	3.88	51.5	5½ hrs.	36.7	98.0	109	126	32	496	....
103	F.	3.29	49	2½ hrs.	37.5	99.5	125	130	40	570	....
104	M.	3.32	51	3 hrs.	36.4	97.6	107	105	32	459	....
Average of 94 subjects...		3.40	50.5	2 days	36.9	98.4	112	143	42	612	....

[1]Computed only for infants of ages between 1½ and 6 days inclusive. See fig. 10, p. 107.

In table 12 the minimum metabolism is expressed first as the total heat-production in 24 hours; second, as the heat-output per kilogram of body-weight per 24 hours; and third, as the heat-output per square meter of body-surface per 24 hours. To explain these values further we have added the records for the body-weight without clothing, the length, the age, the average rectal temperature, and the pulse-rate for the periods of observation included in this table.

TOTAL MINIMUM HEAT-PRODUCTION PER 24 HOURS.

It will be seen that on the basis of the total minimum heat-production per 24 hours new-born infants may range from 193 calories found with subject 67 to a minimum of 95 calories found with subject 82. With so large a number of values as are given in table 12 it is difficult to discover any direct relationship between the body-weight and the total heat-output. The results have therefore been represented graphically in figure 4, in which the total heat-output per 24 hours has been

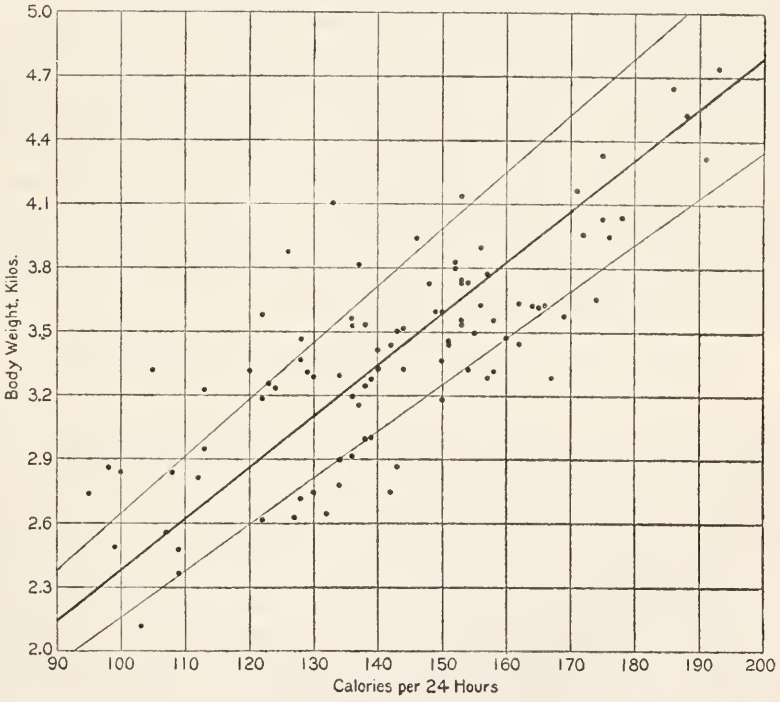


FIG. 4.—Minimum heat-production of new-born infants per 24 hours referred to the body-weight.

plotted against the actual body-weight of the individual infants at the time the metabolism was measured. The approximate average value is indicated in the chart by a heavy black line. As a matter of fact, this line represents a value of 42 calories per kilogram of body-weight per 24 hours.

Although one would expect with a large number of normal new-born infants to find a tendency towards constancy in the minimum metabolism, this chart shows clearly that there is no such constancy, for while in general there is a rough relationship between the total body-weight and the total minimum metabolism, in that for the most part the infants with the larger body-weight have the larger metabolism, yet wide deviations from the average value are found.

Recently it has been the custom among some writers on metabolism to consider a plus or minus metabolism of 10 per cent as a possible normal fluctuation. Although the arbitrary selection of this range seems questionable and we are unable to see what particular value the individual normal figures may have when the variation may admittedly be ±10 per cent, we have indicated these limits on the chart by light lines above and below the heavier line showing the average value. Even under these circumstances we find that a large number of the plotted figures lie outside of the supposedly acceptable limits of variation, for 13 points are above the upper light line and at least 17 points below the lower light line; in other words, some 30 values lie outside of the ±10 per cent limits of variation. Perhaps the most striking illustration of this fact is that of an infant weighing 4.1 kilograms and having a total heat-output per 24 hours of 133 calories. While the majority of the results obtained were well within the ±10 per cent limits, yet, as our observations were made with new-born infants, presumably healthy organisms, which should be perfectly comparable, it is somewhat surprising that variations are found as large as and, indeed, much larger than ±10 per cent.

MINIMUM HEAT-OUTPUT PER KILOGRAM OF BODY-WEIGHT PER 24 HOURS.

The highest value for the minimum heat-production in this series of observations was secured with infant No. 67, who had a body-weight of 4.74 kg., this being the largest body-weight of any of the infants; the lowest minimum heat-production was found with infant No. 82, whose body-weight was only 2.74 kg., although some of the infants had an even smaller body-weight than this. It is obvious, therefore, that body-weight plays an important rôle in the amount of the katabolism and the heat-production per unit of weight must be considered. The values for the heat-production per kilogram of body-weight given in table 12 vary from 52 calories per kilogram with infant No. 50 to 32 calories per kilogram with infants Nos. 84, 101, and 104. It is thus clear that, even per kilogram of body-weight, healthy new-born infants may vary widely in their energy output.

Here again the general trend may be more easily seen in the form of a chart, and the values are therefore given on this basis in figure 5, which shows very clearly the wide variations in the values. Practically no approximation to regularity is apparent, although a con-

siderable number of the points lie within ±10 per cent of the average value of 42 calories. If we draw lines at 38 and 46 to represent these limits of variation, we find that 13 values lie outside of the limits on the one side and 18 values on the other, there being in all some 33 per cent of the total number outside of the limits of variation. To indicate a true average value for a living organism on the basis of weight alone appears, therefore, to be extremely difficult, for even with these normal new-born infants, which are presumably more directly comparable than any other class of human beings, we still find wide variations.

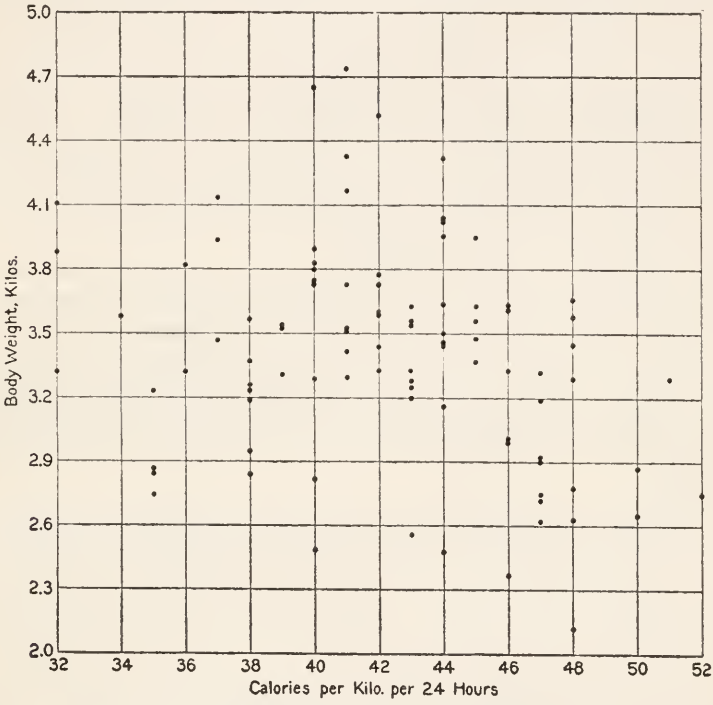


FIG. 5.—Minimum heat-production of new-born infants per kilogram per 24 hours referred to the body-weight.

MINIMUM HEAT-OUTPUT PER SQUARE METER PER 24 HOURS.

Since the cube root of the square of the body-weight represents the general law of growth, and since physiologists, basing their belief upon the observations of Bergmann,[1] Rubner,[2] and Richet,[3] have been inclined to ascribe a particular significance to the relationship between the body-surface and the metabolism, the results computed on the basis of the heat-output per square meter of body-surface per 24 hours have been included in table 12. In our earlier publication[4] it was

[1]Bergmann and Leuckart, Anatomisch-physiol. Uebersicht des Thierreichs, Stuttgart, 1852, p. 272. See also, Bergmann, Ueber die Verhältnisse der Wärmeökonomie der Thiere zu ihrer Grösse, Göttingen, 1848, p. 9.

[2]Rubner, Zeitschr. f. Biol., 1883, **19**, p. 545.

[3]Richet, Archives de Physiol. norm. et path., 1885, **15**, 3d ser., p. 237.

[4]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 166; Benedict and Talbot, Am. Journ. Diseases of Children, 1914, **8**, p. 48.

shown that one of the greatest factors influencing thermogenesis, *i. e.*, the active mass of protoplasmic tissue, probably develops according to the general fundamental law of growth as expressed by the cube root of the square of the body-weight. We feel wholly justified, therefore, in attempting to study the heat-production of these infants on the empirical basis of the heat-output per square meter of body-surface per 24 hours.

The actual measurement of the body-surface of these infants was impossible, as the methods used by Meeh and Lissauer were precluded and no other method giving accurate results was available. At the moment of writing a method which promises well, namely, the Du Bois formula, makes it not at all impossible that body-measurements may be practicable in future investigation of this type. As the data regarding the body-surface of these infants could not be obtained by means of actual measurement, we employed in our calculations the formula of Lissauer, in which the constant 10.3 is multiplied by the cube root of the square of the body-weight.

The results thus obtained show that the average minimum heat-production per square meter of body-surface for the 94 infants was 612 calories per square meter per 24 hours. The largest minimum value was 732 calories with infant No. 81 and the smallest 459 calories with infant No. 104. Even on this basis, which is supposed to equalize not only all animals of similar species but also animals of different species, we do not find comparable values for these infants throughout the whole series.

For a better visualization of the values for the heat-output computed on this basis and given in table 12, the minimum heat-production per square meter of body-surface per 24 hours has been plotted against the body-weight. (See fig. 6.) Here also we find very wide deviations from the average value of 612 calories. Using again, for the purpose of discussion, the hypothetical limits of ± 10 per cent, *i. e.*, 675 calories and 550 calories, respectively, we find that there are 18 values which are more than 10 per cent below the average value and 13 over 10 per cent above the average value. Thus in practically one-third of our observations the results obtained vary more than ± 10 per cent from the average value.

In considering the results obtained with our infants and graphically shown in figure 6, it is of particular interest to refer to the previous conception regarding the heat-production per square meter of body-surface of infants. Although infants have rarely been studied in the first week of post-natal life, the prevailing opinion of physiologists has been that very small and very young animals have proportionally a much larger heat-production than has the adult organism. From the review of the earlier literature given in our first report[1] it will be seen

[1]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914, p. 11; also, Am. Journ. Diseases of Children, 1914, 8, p. 3 and 43.

that the general belief was that infants produced not far from 1,000 calories per square meter of body-surface in common with that supposedly produced by other living organisms. The first considerable reduction in this figure is noted in the writings of Schlossmann and Murschhauser,[1] in which they point out that the basal value is 866 calories per square meter. That this compares favorably with values obtained upon man is shown by Schlossmann and Murschhauser in an interesting way from the results of a single period selected from one of the earlier experiments of Atwater and his associates, in which a heat-production of 828 calories per square meter was observed.

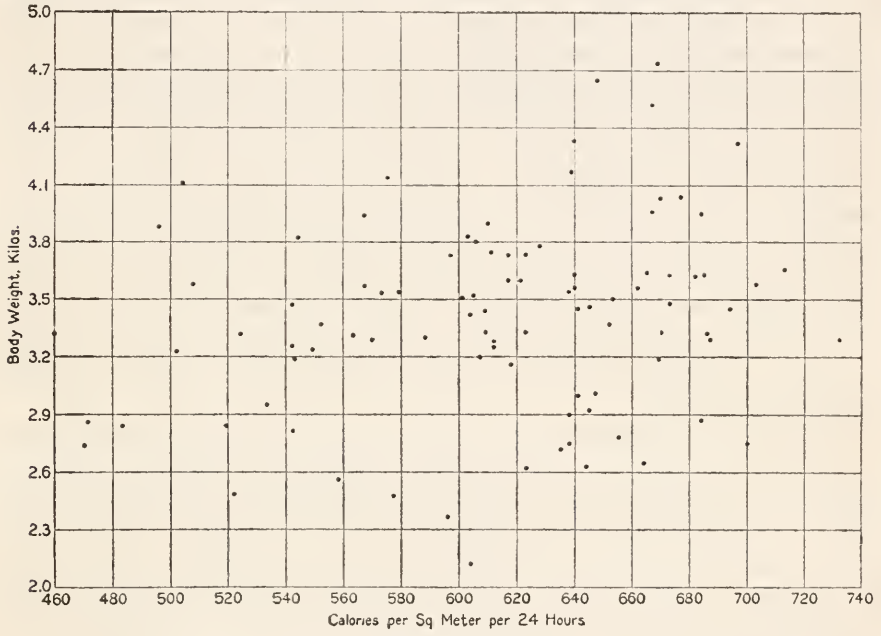


FIG. 6.—Minimum heat-production of new-born infants per square meter of body-surface per 24 hours referred to the body-weight.

We may then say that up to the present time the general opinion has been that young infants had a larger metabolism than adults, that such measurements as were made previous to the observations of Schlossmann and Murschhauser ascribe to the infant a heat-production of 1,000 calories per square meter of body-surface, and that the figure of Schlossmann and Murschhauser reduces this value to 866 calories per square meter of body-surface. It is of further interest that this value of 866 calories per square meter was obtained and reported by Schlossmann and Murschhauser in full recognition of the significance of complete muscular repose during the observations, as is evidenced by their painstaking ocular notations of the degree of muscular repose which were made by a specially trained assistant.

[1]Schlossmann and Murschhauser, Biochem. Zeitschr., 1910, **26**, p. 32.

By reference to table 12, it will be seen that the value of 866 calories is over 100 calories higher than the highest value there recorded, for only 3 observations are above 700 calories per square meter of body-surface, these being obtained with infants 17, 27, and 81, who had a heat-production per square meter of 713, 703, and 732 calories, respectively. The average minimum heat-production of 612 calories per square meter is 254 calories less than the minimum figure of Schlossmann and Murschhauser.

Perhaps no better illustration than this can be found of the difficulties of securing accurate information regarding the probable trend of the metabolism of any group of individuals, in which one case that was carefully and continuously studied gave a value of 866 calories per square meter of body-surface, and a later research, in which 100 or more cases were studied, gave results very much lower, no value being secured within essentially 130 calories of the minimum obtained by the previous investigators. The cause for this discrepancy may readily be found, we believe, in the inherent difficulties in obtaining minimum metabolism measurements when the experimental periods must of necessity be of several hours duration, as was the case with Schlossmann and Murschhauser. Had these observers been able to measure the metabolism of their infant in selected half-hour periods, we have no doubt that their value of 866 calories would have been materially reduced.

The value of 866 calories reported by Schlossmann and Murschhauser was not obtained with a new-born infant, but at the time their observations were published it was the general impression among pediatricians that the metabolism of the new-born infant would be even higher per unit of surface than that of an infant several months old. Accordingly, the difference between our average minimum value of 612 calories and the minimum value of Schlossmann and Murschhauser of 866 calories per square meter of body-surface is, to say the least, most striking.

It should likewise be borne in mind that it is impractical to use here for comparison the heat-production per square meter per 24 hours recorded for the infants studied in our previous research,[1] for these latter include a large number of atrophic infants whose metabolism is admittedly above normal. Although our material is slowly accumulating for an estimation of the metabolism of perfectly normal infants from the time of birth to the age of 2 years, we are not yet in a position to draw conclusions that will necessarily withstand subsequent addition of data; we prefer, therefore, to defer the making of general deductions until later.

INFLUENCE OF AGE UPON THE KATABOLISM.

A general inspection of the values given in table 12 indicates that in the first week of life there is some connection between the age and the

[1]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1914; also, Am. Journ., Diseases of Children, 1914, 8, p. 1.

total katabolism. Although little in the nature of such a relationship may be expected in the first hours after birth, for during the first 24 hours of life there must certainly be a profound readjustment of the organism as a result of the radical change in environment, yet in order that a study may be made of this possible relationship, three charts have been plotted in which the total heat-production per 24 hours, the heat-production per kilogram of body-weight, and the heat-production per square meter of body-surface have been plotted against the age, the minimum figures given in table 12 being used in all cases. (See figures 7, 8, and 9.)

Influence of Age upon the Heat-Production in the First Day.

The total heat-production and the age in days at the time of measurement are compared in figure 7, from which it will be seen that there is a general tendency for the low values for the heat-production to occur

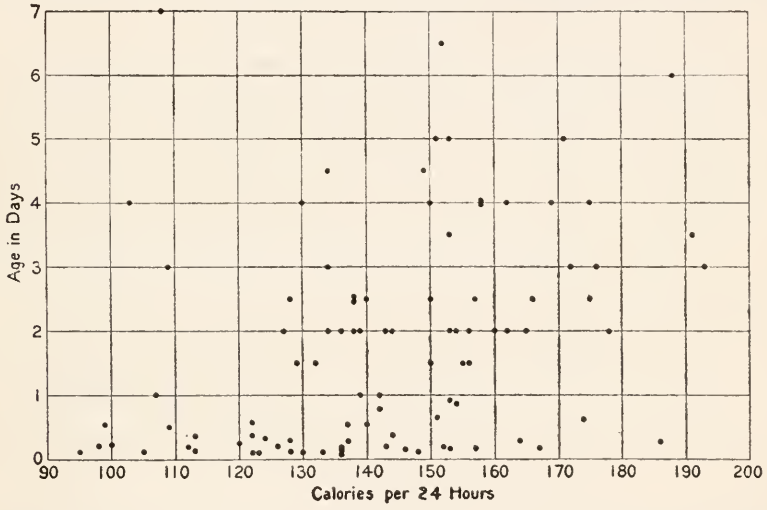


Fig. 7.—Minimum heat-production of new-born infants per 24 hours referred to age.

on the first day of life. The chart does not take into consideration the differences in body-weight, but this is done in figure 8, in which the heat-production per kilogram of body-weight per 24 hours is plotted against the age. In figure 8, also, we find that nearly all of the low values, such as those under 40 calories per kilogram per 24 hours, appear on the first day, even when the weight of the infant is taken into account.

This tendency is shown even more strikingly in figure 9, in which the heat-production per square meter of body-surface per 24 hours is plotted against the age, for all but 4 of the values below 600 calories are found on the first day. It is likewise of interest to note that the two highest values obtained with our infants for the heat-production per square meter of body-surface per 24 hours were also found on this

day. In an attempt to study the heat-production more closely, the chart has been so plotted as to show the values obtained on each half day. We find but little difference between the first and last halves of the first day, however, as the number of observations in the second 12 hours of life were relatively few. As a matter of fact, all values below 520 calories per square meter of body-surface were obtained inside of the first 12 hours of life.

From figures 7, 8, and 9, therefore, it is evident that in our problem of studying the metabolism of infants during the first week of post-natal life we have two distinct phases to consider: (1) the metabolism on the first day of birth, and (2) the metabolism on the remaining 5 or 6 days of the first week. While all of the charts thus far studied

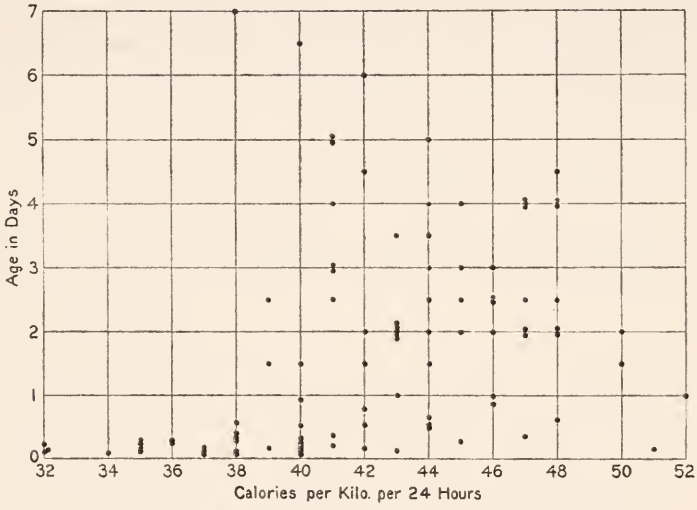


FIG. 8.—Minimum heat-production of new-born infants per kilogram of body-weight per 24 hours referred to age.

indicate clearly that there is no approximation to uniformity shown in the metabolism of new-born infants during the first week of life, the analysis just made shows that a large part, if not indeed the greater part, of the extreme values found in our observations may be attributed to the measurements obtained during the first 24 hours of life. Hence our general conclusion with regard to the metabolism of new-born infants holds true, particularly for the first day of life, namely, that there is no relationship between the total metabolism and either the body-weight or the body-surface. We have to consider, therefore, if, after eliminating the first day of post-natal life, in which there is admittedly a profound physiological readjustment inside the organism, any tendency towards uniformity may be noted in the remaining days of the week.

Influence of Age on the Heat-Production from the Second to the Seventh Day.

With a number of infants experiments were made practically every day during the first week of life. While it was not possible to obtain values showing the minimum metabolism for all of these infants on the succeeding days of the week, we have been able to collect data for a considerable number of the infants for the first 8 days of life which show an approximately minimum metabolism. As for the first 5 days of the week the data were obtained from 35 to 56 subjects, and even on

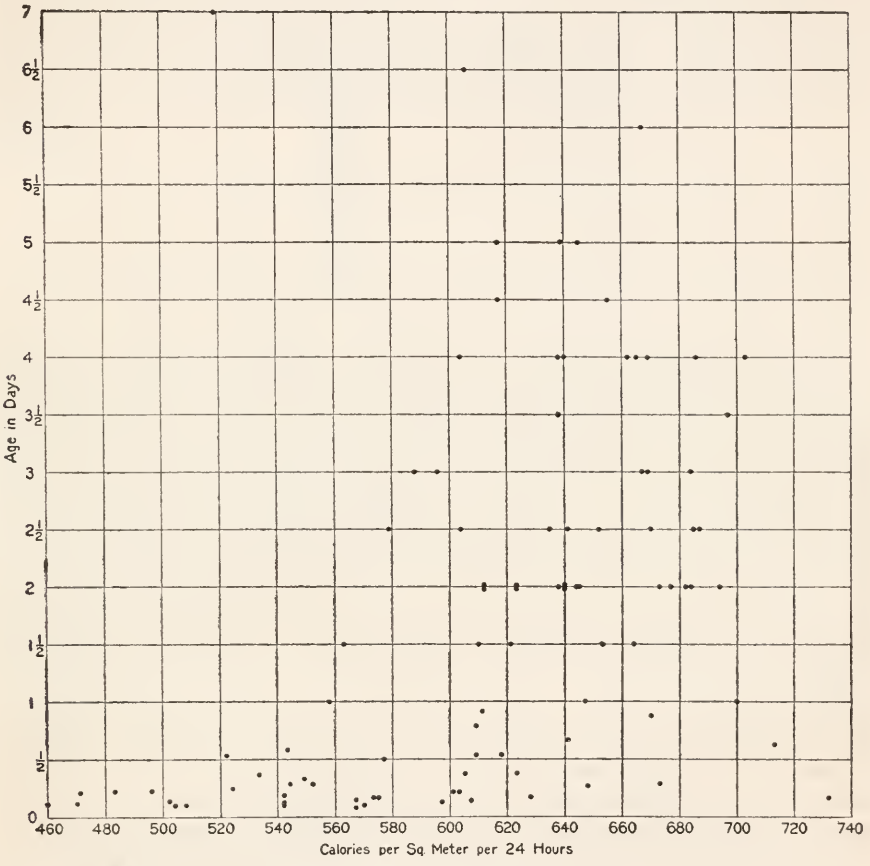


Fig. 9.—Minimum heat-production of new-born infants per square meter of body-surface per 24 hours referred to age.

the last 3 days from 6 to 16 subjects, we may fairly say that they are distinctly comparable. While these values do not represent the actual minimum metabolism, they probably do show, in general, the basal metabolism; they are therefore compared in table 13, in which are given: first, the number of subjects averaged for each day, and second, the average heat-production per square meter of body-surface per 24 hours for the successive days.

Even these *approximately* minimum metabolism values show a heat-production per square meter of body-surface which is considerably lower on the first day than on the other days of the week. After the first day the values remain essentially constant at 660 or 670 calories until the eighth day, the values for 6 subjects on this last day averaging 702 calories.

TABLE 13.—*Approximate basal metabolism of infants during first 8 days after birth.*

Age.	No. of subjects.	Average heat-production (computed) per square meter per 24 hours.
days.		*cal.*
1	56	592
2	47	661
3	49	676
4	46	677
5	35	659
6	16	689
7	8	652
8	6	702

If we turn again to figure 9, in which the *absolutely* minimum values are shown, we find that there is a distinct tendency for the minimum values for the days subsequent to the first day of life to group about a vertical line corresponding to an average of approximately 640 calories per square meter. If the limits of variation used with the other charts are applied, it will be seen that practically all of the data for the last 6 days lie between 580 and 700 calories per square meter of body-surface, the single exception being that of the 7-day-old infant No. 18, with the extraordinarily low heat-production per square meter of 519 calories. Aside from this particular case, therefore, all of the plotted values subsequent to the first day of life lie inside of the ±10 per cent variation from the average value of approximately 640 calories. If the plus or minus variation of 10 per cent is accepted as approximating a physiological law, we may consider this a verification of the fact that after the first 24 hours the heat-production of new-born infants during the first week of life is approximately 640 calories per square meter of body-surface, all values lying inside the limits of ±10 per cent of this average.

INFLUENCE OF LENGTH UPON THE BASAL KATABOLISM.

In our study a large number of plots were made in an attempt to establish some relationship between the metabolism, the body-surface, length, weight, age, and even pulse-rate and body-temperature, as it was believed that the data obtained in the research were sufficiently extensive to justify a thorough search for a mathematical relationship between the measured factors. In a close examination of the original draft of figure 9, on which were noted the lengths of the infants repre-

sented by each point, it was observed that there was a distinct tendency for the shorter infants to have a lower heat-production per square meter of body-surface than the heat-production of the longer infants, and this apparent influence of the length upon the values led us to study the problem critically. The heat-production per square meter of body-surface per 24 hours was therefore divided by the total length of the infant—an admittedly somewhat empirical procedure—and the resulting values were plotted in a chart which is shown in figure 10. Owing to the profound disturbances in heat regulation and the variation in the heat-production values on the first day, only those subjects between $1\frac{1}{2}$ and 6 days of age are included in this chart. Even with these omissions we have the results from 48 infants which are strictly comparable.

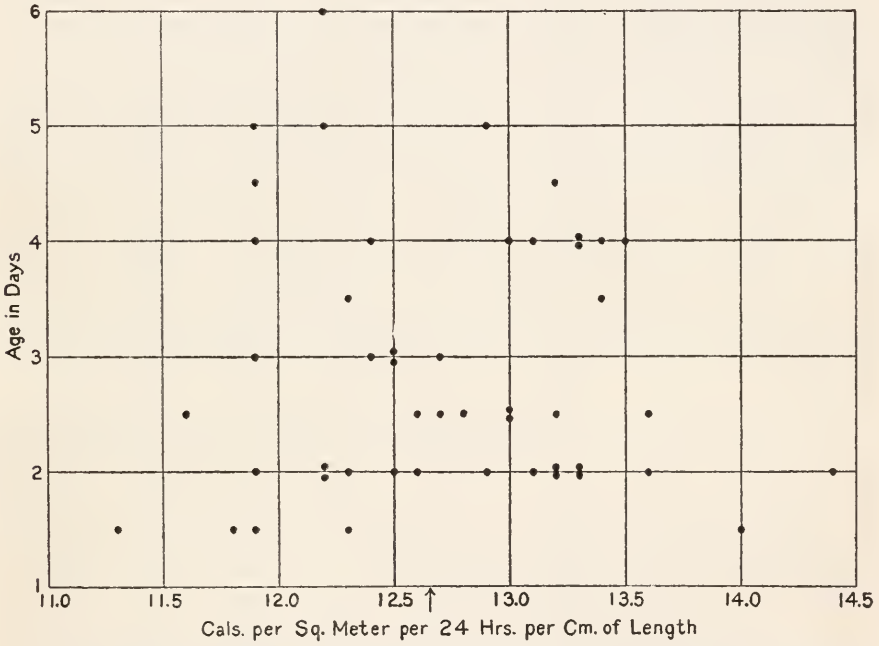


FIG. 10.—Minimum heat-production of new-born infants per square meter per 24 hours, computed per centimeter of length for infants between $1\frac{1}{2}$ and 6 days old. The arrow indicates 12.65 calories.

Nearly all of the points shown in this chart lie between 11.9 calories and 13.4 calories, there being but 3 points below 11.9 calories and only 5 points above 13.4 calories. The 40 points which lie between these values show an average heat-production of 12.65 calories per square meter of body-surface per centimeter of length. The plus or minus variation from this value is, accordingly, about 6 per cent for the 40 infants. It is clear, therefore, that in the 5 days following the first 24 hours of post-natal life, we have a close approximation to constancy in the metabolism of these new-born infants, for while we may reason-

ably question values varying ±10 per cent, a uniformity in values with variations of only ±6 per cent, with but a few striking exceptions, is at least worthy of serious consideration.

From these observations we have derived a formula, cal. $= l \times 12.65$, which takes into consideration both the length and the body-surface and believe that it is possible to compute the minimum heat-production of infants per 24 hours and per square meter of body-surface by multiplying the length l by the constant 12.65, this constant representing the average calories per square meter per 24 hours per centimeter of length as found from actual observations made with this group of infants from $1\frac{1}{2}$ to 6 days old, inclusive. Thus our formula becomes:

$$\text{Total cal.} = l \times 12.65 \times 10.3 \sqrt[3]{\text{wt}^2}$$

The heat-production for the 48 infants shown in figure 10 has been computed by means of this formula and the results are compared in table 14 with the heat-production as determined by indirect calorimetry from the gaseous metabolism. The plus or minus differences between the two values are, for the most part, well inside of 6 per cent, the widest variations being in the case of infants Nos. 53 and 54, with differences of −11.9 per cent and +12.4 per cent, respectively. Aside from infant No. 75, with a variation of −10.6 per cent, practically no other values are found which vary over 7 per cent from the value determined by indirect calorimetry. We believe, therefore, that we are justified in presenting this formula as a reasonably accurate means of computing the minimum heat-production of infants from $1\frac{1}{2}$ to 6 days old.

It is of course not unlikely that, with the progress of the interesting researches of Du Bois on the measurement of body-surface, the Lissauer constant may have to be discarded. As the body-surface is simply an empirical index of the law of growth, we would strongly emphasize our belief in the advisability of securing the most exact measurements; at the same time we would further express our disapproval of any conception of a causal relationship between body-surface and heat-production. As an aid to pediatricians, however, we have computed various data which may be used for obtaining the minimum metabolism of new-born infants. In table 15 the body-surface is given for weights ranging from 2 to 5 kg., as computed with the Lissauer formula. Since, as brought out in the previous discussion, the heat-production per square meter of body-surface becomes a function of length times a constant, we have also computed the theoretical heat-production per square meter per 24 hours for infants varying in length from 45 to 55 cm., using the constant of 12.65 found in our observations. These values are given in table 16. Consequently, to find the total minimum heat-production per 24 hours for any infant, which is of especial value to the pediatrician as indicating a basal value, one has but to multiply

TABLE 14.—*Comparison of minimum heat-production computed by different methods. (Infants 1½ to 6 days old.)*

Subject No.	Length.	Body-weight without clothing.	Surface (Lissauer).	Heat produced per 24 hours.			
				A By formula (length × 12.65 × surface).[1]	B By indirect calorimetry.[2]	Difference.	
						C Amount (A − B).	D Per cent $\frac{C \times 100}{B}$
	cm.	*kg.*	*sq. m.*	*cal.*	*cal.*	*cal.*	
3	52	3.63	0.243	160	166	− 6	− 3.6
4	46.5	3.28	.227	133	139	− 6	− 4.3
6	52	4.32	.273	180	191	−11	− 5.8
8	51	3.48	.236	152	160	− 8	− 5.0
9	51	4.04	.262	169	178	− 9	− 5.1
10	52	3.45	.235	155	162	− 7	− 4.3
12	52.5	4.17	.267	177	171	+ 6	+ 3.5
13	50	3.25	.226	143	138	+ 5	+ 3.6
15	50	3.64	.243	154	162	− 8	− 4.9
16	53	4.03	.261	175	175	0	0
19	53	3.50	.237	159	155	+ 4	+ 2.6
20	52	3.54	.239	157	153	+ 4	+ 2.6
21	50	2.92	.211	134	136	− 2	− 1.5
22	49	2.72	.201	125	128	− 3	− 2.3
25	51.5	3.32	.229	149	158	− 9	− 5.7
26	50	3.46	.235	149	151	− 2	− 1.3
27	52	3.58	.240	158	169	−11	− 6.5
29	50	3.37	.232	147	150	− 3	− 2.0
30	51	3.33	.230	148	144	+ 4	+ 2.8
31	53.5	3.56	.239	162	158	+ 4	+ 2.5
32	47.5	3.42	.234	141	140	+ 1	+ 0.7
33	52	3.73	.248	163	153	+10	+ 6.5
34	50.5	2.90	.210	134	134	0	0
35	54	4.33	.274	187	175	+12	+ 6.9
38	51.5	3.90	.255	166	156	+10	+ 6.4
40	49.5	2.78	.204	128	134	− 6	− 4.5
42	54	3.95	.257	176	176	0	0
43	50	3.62	.242	153	165	−12	− 7.3
48	54.5	4.52	.282	194	188	+ 6	+ 3.2
49	47.5	2.75	.202	121	130	− 9	− 6.9
51	52.5	3.73	.248	165	154	+11	+ 7.1
52	50	3.54	.239	151	138	+13	+ 9.4
53	47.5	2.87	.209	126	143	−17	−11.9
54	50	3.31	.229	145	129	+16	+12.4
56	51.5	3.19	.224	146	150	− 4	− 2.7
59	52	3.60	.241	159	150	+ 9	+ 6
60	52	3.60	.241	159	149	+10	+ 6.7
62	49.5	3.30	.228	143	134	+ 9	+ 6.7
63	47.5	2.37	.183	110	109	+ 1	+ 0.9
65	49	2.63	.197	122	127	− 5	− 3.9
67	54	4.74	.291	199	193	+ 6	+ 3.1
68	46	2.12	.170	99	103	− 4	− 3.9
70	51	3.56	.239	154	153	+ 1	+ 0.7
71	53.5	3.96	.258	175	172	+ 3	+ 1.7
72	50.5	3.29	.228	146	157	−11	− 7.0
74	52	3.63	.243	160	156	+ 4	+ 2.6
75	47.5	2.65	.197	118	132	−14	−10.6
90	50	3.00	.214	135	138	− 3	− 2.2

[1]See fig. 10, p. 107, and table 16, p. 110. [2]See table 12 p. 95.

the values given in table 16 by the surface area as indicated in table 15. The minimum basal metabolism thus found will lie for the most part within a ±6 per cent limit, only a few instances being found outside of this and these rarely varying more than 10 per cent from the average value.

TABLE 15.—*Body-surface computed from the Lissauer formula* ($10.3\sqrt[3]{W^2}$).

Body-weight.	Body-surface.	Body-weight.	Body-surface.	Body-weight.	Body-surface.	Body-weight.	Body-surface.
kg.	*sq. m.*	*kg.*	*sq. m.*	*kg.*	*sq. m.*	*kg.*	*sq. m.*
2.00	0.163	2.80	0.205	3.55	0.239	4.30	0.272
2.05	.166	2.85	.207	3.60	.241	4.35	.274
2.10	.169	2.90	.210	3.65	.244	4.40	.277
2.15	.172	2.95	.212	3.70	.246	4.45	.279
2.20	.174	3.00	.214	3.75	.249	4.50	.281
2.25	.177	3.05	.217	3.80	.251	4.55	.283
2.30	.179	3.10	.219	3.85	.253	4.60	.285
2.35	.182	3.15	.222	3.90	.255	4.65	.287
2.40	.184	3.20	.224	3.95	.257	4.70	.289
2.45	.187	3.25	.226	4.00	.260	4.75	.291
2.50	.190	3.30	.228	4.05	.262	4.80	.293
2.55	.192	3.35	.231	4.10	.264	4.85	.295
2.60	.195	3.40	.233	4.15	.266	4.90	.297
2.65	.197	3.45	.235	4.20	.268	4.95	.299
2.70	.200	3.50	.237	4.25	.270	5.00	.301
2.75	.202						

TABLE 16.—*Heat values (per sq. meter per 24 hrs.) computed for varying lengths. (Infants 1½ to 6 days old, inclusive.)*

Length.	Length × constant (12.65).[1]	Length.	Length × constant (12.65).[1]	Length.	Length × constant (12.65).[1]
cm.	*cal.*	*cm.*	*cal.*	*cm.*	*cal.*
45.0	569	48.5	614	52.0	658
45.5	576	49.0	620	52.5	664
46.0	582	49.5	626	53.0	670
46.5	588	50.0	633	53.5	677
47.0	595	50.5	639	54.0	683
47.5	601	51.0	645	54.5	689
48.0	607	51.5	651	55.0	696

[1]See fig. 10, page 107.

It should further be emphasized that in the foregoing discussion we have been dealing specifically with the minimum basal metabolism, and that this would not, except in extremely rare instances, correspond to the total 24-hour heat-production of an infant living in a private hospital ward or the home nursery. The influence of feeding and muscular activity would obviously be superimposed upon these minimum values, but we believe that we are correct in saying that this is the first time we have information which may be considered as founded upon sufficiently extensive data to give us a true basal value for the minimum

metabolism of new-born infants. The problem now before us is to determine approximately the influence of the various superimposed factors which make up a day of ordinary activity.

INFLUENCE OF ACTIVITY UPON THE BASAL KATABOLISM.

As has already been pointed out, the minimum metabolism values recorded in this report indicate only the metabolism when the infants studied were in a condition of practically complete muscular repose. As a matter of fact, infants are not in complete muscular repose during the entire first week of life, and there are periods in which the activity varies from a general restlessness and movement of the limbs to paroxysms of severe crying. The probable maximum values for the metabolism are therefore of interest. The maximum values observed with 93 of our infants, *i. e.*, the values found in the periods when the maximum respiratory exchange took place, are given in table 17 and are there compared with the minimum values previously recorded in table 12. The percentage increase found in the maximum periods as compared with the minimum periods is also given in table 17. It should be borne in mind that the values given in table 17 are not the highest values possible as a result of muscular activity, but are the highest that were observed for the individual infants in our study. It is probable, however, that the 211 per cent increase shown by one of the infants represents approximately the possible maximum.

Before the measurements of the respiratory exchange were begun most of the infants were naturally somewhat active as a result of bathing and dressing and their transportation from the hospital to the observation room. A considerable proportion of the maximum values were therefore found in the preliminary periods of the observations, but a large number of these values were also obtained in other periods. With a few infants the increase shown in the maximum period was hardly 4 per cent, but the average for the 93 subjects shows an increase of 65 per cent in the maximum heat-production as compared with the minimum. In some instances this average difference was very greatly increased. Thus, values over 100 per cent were found in 10 instances, the highest value being that of infant No. 89, with which an increase of 211 per cent was found in the maximum period. On the other hand, a large majority of the subjects showed an increase of only 40 to 80 per cent above the minimum.

Since other writers have reported a very much smaller increment in the basal metabolism as a result of crying and muscular activity, a close analysis of our figures is essential. A possible criticism may be raised that these computations were based entirely upon the carbon-dioxide output, making due allowance for the variations in the respiratory quotients in computing the calories produced. We have therefore recomputed the increment in metabolism for a considerable number

TABLE 17.—*Maximum and minimum heat-production in observations on new-born infants.*

Subject No.	Pulse-rate.		Heat produced (computed) per 24 hours.			Subject No.	Pulse-rate.		Heat produced (computed) per 24 hours.		
	Max. period.	Min. periods.[1]	Max.	Min.[1]	Increase, maximum over minimum		Max. period.	Min. periods.[1]	Max.	Min.[1]	Increase, maximum over minimum
			cal.	*cal.*	*p. ct.*				*cal.*	*cal.*	*p.ct.*
2	107	99	[2]195	152	28	58	120	111	[2]180	139	29
3	135	97	[2]305	166	84	59	132	112	[2]271	150	81
4	113	105	[2]221	139	59	60	142	117	213	149	43
5	128	112	[2]242	137	77	61	119	121	[2]136	123	11
6	160	116	381	191	99	62	146	116	[2]363	134	171
8	162	117	267	160	67	63	113	125	[2]185	109	70
9	103	109	[2]243	178	37	64	122	98	[2]193	128	51
10	101	116	[2]227	162	40	65	129	116	[2]166	127	31
12	130	112	[2]249	171	46	66	136	103	[2]205	122	68
13	135	113	352	138	155	67	135	122	[2]283	193	47
15	131	122	286	162	77	68	141	113	185	103	80
16	139	113	312	175	78	69	124	110	[2]222	142	56
17	126	118	323	174	86	70	125	109	270	153	76
18	110	105	[2]200	108	85	71	119	106	[2]255	172	48
19	118	114	205	155	32	72	110	110	[2]210	157	34
20	129	110	209	153	37	73	162	106	248	164	51
21	126	121	[2]217	136	60	74	118	94	[2]225	156	44
22	139	114	[2]303	128	137	75	118	100	[2]185	132	40
25	135	123	233	158	47	76	110	101	[2]193	137	41
26	124	113	269	151	78	78	125	101	[2]153	109	40
27	119	111	[2]237	169	40	79	127	116	[2]257	153	68
29	139	112	326	150	117	80	146	109	290	128	127
30	125	114	[2]195	144	35	81	126	114	[2]196	167	17
31	127	117	[2]218	158	38	82	106	101	131	95	38
32	115	116	[2]193	140	38	83	138	131	[2]332	148	124
33	140	129	[2]225	153	47	84	139	109	227	133	71
34	135	115	200	134	49	85	102	109	[2]169	144	17
35	123	109	[2]244	175	39	86	104	103	[2]231	120	93
36	138	129	[2]220	154	43	87	145	118	259	146	77
37	117	119	[2]134	99	35	88	106	96	[2]172	122	41
38	123	127	[2]225	156	44	89	162	107	386	124	211
39	133	105	[2]198	113	75	90	92	86	[2]181	138	31
42	134	113	[2]244	176	39	91	115	113	[2]199	140	42
43	135	119	[2]244	165	48	92	136	112	[2]240	157	53
44	131	103	225	136	65	93	146	127	[2]239	136	76
45	122	110	[2]157	107	47	94	135	117	[2]237	136	74
46	158	126	239	152	57	95	142	123	[2]176	100	76
47	119	107	[2]249	143	74	96	120	99	[2]174	113	54
48	181	132	[2]515	188	174	97	117	113	[2]178	112	59
49	140	114	[2]226	130	74	98	123	102	160	98	63
50	94	89	[2]147	142	4	99	124	103	[2]228	122	87
51	120	96	[2]264	154	71	100	134	130	[2]295	186	59
52	138	114	209	138	51	101	158	109	[2]251	126	99
53	160	126	315	143	120	103	123	125	[2]215	130	65
54	112	106	[2]223	129	73	104	135	107	176	105	68
55	126	124	[2]194	151	28						
56	141	121	[2]209	150	39	Average of 93 subjects	129	112	234	143	65
57	154	105	345	153	125						

[1]See table 12, p. 95.

[2]Maximum calculated from the carbon dioxide produced during a preliminary period for which the respiratory quotient was not determined.

of the infants who showed a large increase in the heat-production during the maximum period, using the oxygen consumption as a basis of calculation. These are compared in table 18 with the values previously calculated from the carbon-dioxide production. As will be seen by reference to this table, the values found upon this basis vary but slightly from those computed from the carbon-dioxide production. For example, the large increment of 211 per cent shown by infant No. 89 in the maximum period on the basis of the carbon-dioxide production becomes 219 per cent when the calculation is made on the basis of the oxygen consumption, while with infant No. 13 the increment of 155 per cent becomes 137 per cent on the basis of the oxygen consumption. All of the other computations lie distinctly inside these limits.

TABLE 18.—*Periods of maximum heat-production computed from the oxygen consumption.*

Subject No.	Duration of period.	Oxygen consumed.	Heat produced (computed) per 24 hours.	Increase of maximum over minimum.	
				Computed from oxygen.[1]	Computed from carbon dioxide.[2]
	min.	*liters.*	*cal.*	*p. ct.*	*p. ct.*
6	29	1.46	341	79	99
13	31	1.45	327	137	155
15	33	1.33	289	78	77
16	43	1.87	308	76	78
26	26	.96	258	71	78
29	24	1.14	331	121	117
57	25	1.19	332	117	125
68	37	1.01	187	82	80
80	62	2.34	262	105	127
87	62	2.21	251	72	77
89	27	1.55	395	219	211

[1]The average respiratory quotient for the observation was used in the computation as was done in computing the values in table 17.
[2]See table 17.

In view of this comparison, we may therefore have every confidence in the values given in table 17, and fairly conclude that with the average infant the metabolism may, on the average, be increased approximately 65 per cent above the minimum value, with the possibility of an increase of 200 per cent, or even more when there is extreme restlessness and crying.

PULSE-RATE.

It has been clearly demonstrated in previous researches in this laboratory that the pulse-rate is one of the best indices of the internal muscular activity or degree of cellular stimulus, and this fact was taken into consideration in selecting the minimum metabolism periods. In the earlier investigation the relationship between the pulse-rate and

the metabolism was specifically studied,[1] but in the research on the metabolism of new-born infants, the recording of the pulse-rate was only incidental to the measurements of the metabolism and a special assistant was not assigned to this routine; the method of taking the records was therefore somewhat defective. Nevertheless, from 6 to 8 observations were made during each 30-minute period and a sufficient number of periods were used in averaging to give reasonable assurance of the validity of the average values obtained. A study of the pulse-records is therefore desirable.

The observations of the pulse-rate in the previous research showed the very wide variations which may reasonably be expected to occur in a short period. The infants studied at that time included only a few new-born infants, yet the records obtained in the later research show the same striking changes in the pulse-rate that were found with the older infants. This may be seen in table 17,[2] in which the average pulse-rates for the periods of minimum metabolism are given and compared with those for the periods of maximum metabolism. It should be borne in mind that these values do not represent the minimum or maximum pulse-records, but only the average pulse-rates for those periods in which the minimum or maximum metabolism was found for the individual infants. The comparison of the values obtained in these periods has a special interest in our study of the minimum and maximum metabolism of new-born infants.

The values for the pulse-rate during the periods of minimum metabolism ranged from 86 for infant No. 90 to 132 for infant No. 48, the average for the 93 subjects being 112. When we examine the average values for the periods of maximum metabolism, certain anomalous values are apparent, but usually the pulse-rate for the minimum period was distinctly lower than that found during the maximum period, the average value for the maximum period being 129, or 17 beats higher than the average value for the minimum periods. Very great differences are, however, frequently found between the highest and lowest values. For instance, with infant No. 6 the pulse-rate for the maximum period was 160 and for the minimum period 116, and with infant No. 8 the averages were 162 and 117 respectively. With infant No. 73 a still greater difference was found, the values being 162 for the maximum and 106 for the minimum; essentially the same values were found for infant No. 89, with whom the metabolism increased 211 per cent. We may say with perfect propriety, therefore, that in general with new-born infants the pulse-rate increases with the metabolism, but we do not find so close an approximation to the mathematical relationship between the increment in the pulse-rate and the metabolism as was observed with the fasting man recently studied in this laboratory.[3]

---

[1]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1915, p. 130.
[2]See page 112. [3]Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915, p. 350.

TABLE 19.—*Pulse-rate of infants during periods of approximately minimum heat-production in first 8 days after birth.*

Subject No.	Sex.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.
2	Female	...	...	...	...	...	...	103	95
3	Male	...	95	99	112	...	...	...	...
4	Female	...	101	108	119	103	...	...	...
5	Male	112	103	...	...	...	...	...	...
6	Male	...	...	136	121	114	...	...	...
8	Male	111	...	144	129	...	...	...	...
9	Female	...	106	109	...	...	...	...	...
10	Male	...	113	117	...	...	...	...	...
12	Female	...	...	...	104	117	120	128	...
13	Female	...	113	113	113	...	...	...	...
15	Male	...	...	125	...	121	119	...	121
16	Female	115	110	107	...	...	121	...	...
17	Female	118	...	...	123	...	...	...	...
18	Male	...	...	107	115	109	...	105	...
19	Male	116	114	...	108	96	111	...	...
20	Female	110	...	...	110	109	...	...	...
21	Female	116	121	...	119	120	...	...	...
22	Female	...	...	114	115	...	123	...	...
25	Male	...	...	127	120	124	129	...	123
26	Female	...	...	...	117	...	106	...	...
27	Male	...	117	116	116	105	...	124	...
29	Female	...	113	113	107	...	...	...	...
30	Male	...	125	102	105	...	...	113	...
31	Male	...	...	...	...	117	...	...	...
32	Male	128	...	...	111	118	...	...	...
33	Male	...	...	...	122	125	138	136	148
34	Female	...	...	116	123	131	138	...	...
35	Female	...	...	111	...	107	119	110	114
36	Male	129	...	...	...	...	...	...	...
37	Female	119	121	130	120	124	...	...	...
38	Female	125	127	132	...	...	...	...	...
39	Female	105	...	122	115	124	...	...	...
40	Female	...	117	...	115	...	109	...	...
42	Female	120	112	123	114	125	...	...	...
43	Female	...	137	119	...	...	...	...	...
44	Female	103	...	112	...	124	...	...	...
45	Female	99	115	107	...	...	...	...	...
46	Male	122	134	...	109	106	114	...	...
47	Male	107	130	115	105	122	136	...	...
48	Female	...	138	...	132	131	132	...	156
49	Female	...	115	111	113	114	...	...	...
50	Female	...	89	...	...	...	...	...	...
51	Male	99	114	93	108	111	...	...	...
52	Female	...	124	110	115	111	...	...	...
53	Male	...	...	126	...	...	...	...	...
54	Male	101	106	120	114	...	...	...	...
55	Male	124	...	...	...	...	...	...	...
56	Male	...	...	...	126	119	119	...	...
57	Male	109	99	...	...	119	...	...	...
58	Female	115	107	...	113	...	...	...	...
59	Female	...	115	108	...	...	120	...	...
60	Male	...	...	...	...	117	...	...	...
61	Male	121	122	129	...	...	...	...	...
62	Male	118	118	126	114	115	...	...	...
63	Female	...	112	118	125	110	...	...	...
64	Female	98	112	125	...	131	...	...	...
65	Female	106	126	137	121	...	...	...	...
66	Male	103	119	124	131	134	...	...	...
67	Male	...	126	...	125	115	...	...	...

TABLE 19.—*Pulse-rate of infants during periods of approximately minimum heat-production in first 8 days after birth*—Continued.

Subject No.	Sex.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.
68	Male	...	...	...	115	109	...	...	...
69	Male	112	109	112	...	...	...	...	...
70	Male	...	107	100	111	...	...	...	...
71	Male	...	...	111	...	100	...	...	...
72	Male	...	...	110	...	...	...	...	...
73	Male	106	131	131	121	...	...	...	...
74	Male	...	94	...	...	...	...	...	...
75	Male	...	100	113	115	...	...	...	...
76	Male	101	...	...	...	...	...	...	...
78	Male	101	...	...	...	...	...	...	...
79	Female	116	124	127	106	...	...	...	...
80	Male	109	...	...	124	...	...	...	...
81	Female	114	...	...	...	...	...	...	...
82	Male	101	...	...	...	...	...	...	...
83	Male	131	122	...	...	...	...	133	...
84	Female	109	...	115	...	...	...	...	...
85	Male	109	...	...	...	...	...	...	...
86	Female	103	...	...	98	...	...	...	...
87	Male	118	113	...	...	...	...	...	...
88	Female	96	...	...	...	...	...	...	...
89	Male	107	112	123	129	...	...	...	...
90	Male	116	88	82	...	...	...	...	...
91	Female	113	105	...	...	...	...	...	...
92	Female	112	...	112	...	...	...	...	...
93	Male	127	...	...	...	...	...	...	...
94	Male	117	...	118	...	...	...	...	...
95	Female	123	...	...	...	...	...	...	...
96	Female	99	...	...	...	...	...	...	...
97	Female	113	...	...	...	...	...	...	...
98	Female	102	...	...	...	...	...	...	...
99	Male	103	...	...	...	...	...	...	...
100	Male	130	...	...	...	...	...	...	...
101	Male	109	...	...	...	...	...	...	...
103	Female	125	...	...	...	...	...	...	...
104	Male	107	...	...	...	...	...	...	...
	Average	112	114	116	116	116	122	119	126

This discussion of the pulse-rate of new-born infants has thus far dealt with the average pulse-records during the periods with either maximum or minimum metabolism, irrespective of the age of the infant, which varied from 1 to 7 days. Since a study of the probable trend of the pulse-rate of infants during the first week of life may be of particular significance, we have gathered together in table 19 the pulse-rate prevailing during the periods which were selected for the comparison from day to day of the minimum heat-production. (See table 13.) The metabolism in these periods can be considered absolutely minimum in but relatively few instances, but the values do represent the best which could be obtained from the data available for the first 8 days of life. The lowest average pulse-rate, *i. e.*, 112, was found on the first day of life. For the next 4 days the pulse-rate remained

essentially constant, being 114 for the second day and 116 for the three following days. At the end of the week there was a distinct increase, the pulse for the sixth, seventh, and eighth days averaging 122, 119, and 126, respectively.

While we would again emphasize the fact that these pulse-rate observations were wholly incidental to the studies of the metabolism, yet our previous experience has led us to be so cautious in our selection of average values and of minimum values that we may say with confidence that these figures represent the average minimum values for the pulse-rate of a considerable number of new-born infants during the first 8 days of life. The fact that the low pulse-rate for the first day is coincidental with a low average body-temperature and heat-production is only what would naturally be expected in view of the results obtained in our previous researches and bears out the theory that the best indices of internal muscular activity or internal cellular activity are the pulse-rate and the body-temperature. Under normal conditions fluctuations in the body-temperature are not so great as to define sharply the relationship between the body-temperature and the metabolism, except when there is a febrile temperature. With the supercooling of these infants, however, the low pulse-rate and its attendant low metabolism and low temperature are strikingly in accord.

PHYSIOLOGICAL NEEDS *VS.* SUPPLY.

As a result of this study of the metabolism of the new-born infant, certain fundamental values may be considered as definitely established, namely, the basal energy requirements of the new-born infant for the 5 days following the first 24 hours of life. Our calculations of the minimum metabolism, upon which we base our discussion almost exclusively, show a remarkable degree of uniformity in these values. From the tables recording the minimum and maximum metabolism, data may be obtained for also computing the approximate energy requirements of the new-born child during a day of varied activity. The maximum values have been shown to vary enormously in individual cases, but the results of the whole series average 65 per cent above the basal metabolism.[1]

In estimating such requirements we are dealing only with the problem of maintenance, assuming that during the first week we may disregard the requirements for actual growth (at least for the purposes of discussion). Hence the primal consideration may be stated to be: Is the normal food-supply of the new-born infant during the first week sufficient for maintenance, disregarding any needs for growth? As the evidence that we have accumulated may have a certain directly practical value in this connection, the energy output and its quantitative relations to the energy intake may very properly be considered. Practical experience, particularly in regard to the noticeable loss in weight

[1]See p. 112.

and the apparent scant supply of colostrum, leads us to expect, *a priori*, that there is a lack of balance between intake and output. To attempt any readjustment demands either (1) a reduction of the energy output or (2) a more adequate food-supply, or a combination of both factors.

THE CONSERVATION OF ENERGY.

The energy output depends largely upon the heat-regulation of the body. The values previously presented have indicated that this heat-regulation is very imperfect during the first day after birth, since both minimum and maximum values for the basal metabolism per unit of weight or surface area are noted on this day.[1] Important supplementary evidence as to a greatly disturbed heat-regulation may be found in a study of the body-temperature of these infants, for body-temperature is the resultant of thermogenesis and thermolysis, and if the latter prevails, there is a falling temperature. The well-known factors influencing body-temperature in the adult, such as muscular activity and exposure to a temperature environment differing greatly from that of the body, are immediately recognized as factors entering into the early life of the new-born infant, thus making a consideration of the fluctuations in the body-temperature imperative in any adequate discussion of the problem of heat-regulation in the body of the new-born infant.

Body-Temperature.

The body-temperature of these infants was recorded in practically all instances just before and just after the observation of the respiratory exchange, and the data obtained are given with the other statistical data in table 9.[2] In many of the observations on the first day after birth, the body-temperature rose while the infant was inside the respiration chamber. It would appear, therefore, that the effect of the labor, the bath, and the exposure incident thereto was to lower the temperature below normal. High temperatures were rarely noted with any of the infants, but occasionally very low records were obtained when there had been undue exposure, such as in the bath given before the observation of the respiratory exchange. The low temperature due to this previous exposure persisted for some time, but the temperature gradually attained the normal height for an infant of this age.

In order that a more definite comparison may be made of the body-temperature records during the first day after birth with those obtained in the days following, the average rectal temperature of our infants for each of the first 8 days is given in table 20. To study more closely the temperature for the first day, we give also the records obtained with infants studied before they were 12 hours old and those studied between the twelfth and twenty-fourth hours. On the day of birth 48 infants

[1]See figures 7, 8, and 9, pp. 103, 104, and 105. [2]See pages 46 to 79.

had an average rectal temperature during the first 12 hours of 36.7° C. (98.1° F.) and during the last 12 hours 26 infants had an average temperature of 36.9° C. (98.4° F.). The average rectal temperature for the infants studied on the first day after birth was 36.8° C. (98.2° F.), on the second day 37.1° C. (98.8° F.), on the third day 37.2° C. (99.0° F.), on the fourth day 37.0° C. (98.6° F.), and on the fifth day 36.9° C. (98.5° F.). While admittedly the records for the sixth, seventh, and eighth days were obtained with relatively few infants, the average results approximate those for the days immediately preceding, being 37.0° C. (98.6° F.). It is perfectly clear from these data, therefore, that the average rectal temperature of infants on the first day after birth is at least 0.3° C. (0.6° F.) lower than on the second day. This observation, taken in connection with the fact that the infants during the first 12 hours had a slightly lower temperature than those studied during the last 12 hours, would imply that the temperature gradually increased from the first to the third day, and, indeed, even during the first day, or that it was lowered during the first day by the bath.

TABLE 20.—*Average rectal temperature of infants during first 8 days after birth.*

Age.	No. of subjects.	Average temperature.		Age.	No. of subjects.	Average temperature.	
		°C.	°F.			°C.	°F.
1 to 12 hrs..	48	36.7	98.1	4 days....	51	37.0	98.6
12 to 24 hrs..	26	36.9	98.4	5 days....	41	36.9	98.5
1 day.....	74	36.8	98.2	6 days....	22	37.0	98.6
2 days.....	65	37.1	98.8	7 days....	16	36.9	98.5
3 days.....	62	37.2	99.0	8 days....	9	37.1	98.8

With one infant the rectal temperature was recorded at short intervals for about 5 hours, beginning 1 hour after birth. Oiling and a bath preceded the observations in the respiration chamber. During this preliminary care the child was inadvertently subjected in the hospital to a longer exposure than usual and the temperature of the room was also lower than had been customary.[1] The records of the rectal temperature are given in table 21, those while the infant was in the respiration chamber beginning with $4^h\ 56^m$ p. m. While the rectal temperatures were being taken in the chamber there was necessarily the same slight exposure which is customary when such temperature records are made in the hospital, but great care was taken to keep the infant well wrapped up at these times.

From the records in table 21 it will be seen that the rectal temperature rose steadily and somewhat rapidly throughout the entire period. It is not possible, however, to average these values with the temperature records obtained with the other infants, for in the majority of

[1]The temperature of the room was 71° F., while usually it is 80° F. or more.

cases the exposure during the bath was less than in this particular instance. On the other hand, the exposure after birth was probably much less with our infants than is usual in ordinary hospital practice or in caring for the new-born child in the home. Accordingly we may fairly conclude that when the infant is bathed in the usual way the temperature during the first 24 hours is distinctly subnormal.

That the environmental temperature plays a very great rôle in its effect upon the body-temperature, particularly during the first day of life, is also shown in certain of Hasselbalch's studies, in which the recorded temperatures are frequently extraordinarily low. Thus in table 1 he gives rectal temperatures as low as 32.8° C. and 33.4° C., while in table 3 he gives two temperatures of 33.4° C. and 33.1° C.[1]

TABLE 21.—*Rectal temperature of an infant taken at frequent intervals during early hours after birth.*

Time.	Rectal temperature.		Time.	Rectal temperature.	
May 14, 1915:	°C.	°F.	May 14, 1915—con.	°C.	°F.
4h 06m p. m.[1]	37.0	98.6	6h 44m p. m.	36.0	96.8
4 17 p. m.	37.0	98.6	7 09 p. m.	36.0	96.8
4 46 p. m. (?)	36.4	97.6	7 34 p. m.	36.3	97.4
4 56 p. m.[2]	35.2	95.4	7 59 p. m.	36.3	97.4
5 23 p. m.	35.2	95.4	8 25 p. m.	36.4	97.6
5 49 p. m.	35.4	95.8	8 50 p. m.	36.4	97.6
6 17 p. m.	35.7	96.2			

[1]Time of birth 4h 01m p. m. Bath (oiled first and then bathed in water at 102° F.) given between 4h 20m p. m. and 4h 45m p. m.; temperature of room 71° F.
[2]Placed in the respiration chamber at 4h 56m p. m.

The observations made with our infants indicate that there is a distinct correlation between the body-temperature of the infant and the total metabolism, for on the days with low body-temperature the total metabolism was likewise low. Indeed, in some instances when the records of the temperature distinctly indicated a supercooling, the advisability of using certain of the data has been questioned. Since it is seldom that we find these low temperatures other than on the first day after birth, it is highly probable that they are due solely to the exposure incidental to the birth, the subsequent bath, and other special details of the care of a new-born infant. It is of peculiar significance, therefore, that on the first day, when the low temperatures predominate, we find likewise a somewhat lower metabolism per kilogram of body-weight and per square meter of body-surface than on the subsequent days, thus bearing out the contention that the metabolism is considerably affected by the body-temperature.

When we make a critical analysis of Hasselbalch's figures, however, we find it impossible to determine precisely the influence of the body-temperature upon the metabolism, for we have no evidence as to the

[1]See pages 20 and 22. It should be stated here that Hasselbalch calls attention to the possible errors in these observations.

exact degree of the muscular repose of the infant. It is not improbable that the chilling effect of too low a temperature and exposure during a bath may produce shivering and, indeed, crying, as the child attempts temperature regulation by increased muscular activity. The low metabolism induced by the low temperature may therefore be more than compensated by an increase in the metabolism due to the efforts of the infant to maintain the temperature by muscular movements.

Since the metabolism is so profoundly affected by the influence of various factors upon the body-temperature, it would appear logical that some means should be found for compensating for the defective temperature regulation of the new-born infant—a deficiency frequently resulting in a disturbed katabolism.

Methods for Reducing the Energy Loss.

Various methods for preventing an excess energy output during the first days of an infant's life are used in ordinary practice. Every good nurse, whether trained or untrained, knows that an infant must be kept warm and comfortable and does everything in her power to make him so, thus instinctively conserving the energy. Excess katabolism is, for the most part, due to muscular activity. At birth the infant emerges from warm surroundings in which the temperature was 37° C. (98.6° F.) into air which is many degrees colder, presumably 26.7° C. (80° F.); the shock of the cold air causes him to cry. This crying, however, is necessary for his future welfare, as it expands his lungs with air and prepares them for their future work. The preliminary fit of crying comes naturally to most infants and is usually induced with others.

After this fit of crying every legitimate effort should be made, especially during the first days of life, to reduce the muscular activity to a minimum, and thus prevent a waste of energy. The more time the infant spends in quiet sleep, the less will be the katabolism. When a healthy, new-born baby is awake, crying, and active, it is usually uncomfortable and it cries from an instinct of self-preservation. This discomfort may be due to chilling, improperly adjusted clothing, wet or soiled diapers, too high a temperature of the hot-water bottles, hunger, indigestion, or a few pathological processes.[1] The infant should be made comfortable by attention to such minor details as dry diapers, a comfortable bed, protection from glaring sunlight, and similar precautions.

When too low a temperature environment produces chilling, the infant instinctively attempts to raise the body-temperature by physical activity and thus compensate for the loss of heat. For energy conservation a warm environment is imperatively necessary and all undue exposure must be avoided. Since there must in consequence be more

[1]Since this monograph deals only with the normal, healthy infant, it is not necessary to speak further of the possible diseases which may cause an infant to cry.

or less exposure and a lowering of the body-temperature in bathing the infant, especially in a room of ordinary temperature, there is good reason for believing that the bath should be omitted on the first day and the infant should be simply oiled. This precaution may be especially applicable in the case of poorly-nourished, weak, or premature infants. The baby should also be kept warm with artificial heat, hot-water bottles commonly being used. With the infants in our observations a warm environment was produced inside the respiration chamber by raising the temperature of the water-jacket surrounding it. The fact that the body-temperature rose in many of the observations with the respiration chamber, especially on the first day, would indicate that the conditions were favorable for conserving the energy output during the first hours after birth, when the heat regulation of the body was markedly imperfect.

Yet another reason for the excess muscular activity during these first days of an infant's life may be the actual need of food, for certain muscular movements are always associated with hunger. The methods for supplying this need are, however, more properly discussed in connection with the quantitative relations of the energy intake.

THE ENERGY INTAKE.

The results obtained in our study of the new-born infant show that the energy requirements during the first week of life are by no means small. While these requirements are not so large per kilogram of body-weight and per square meter of body-surface as has been commonly supposed, nevertheless there is a considerable draft upon body-material, at least during the early days of an infant's life, and it is not true that the body has a superabundant supply of glycogen available for this excessive draft upon its material. As has already been noted,[1] while there is a moderate amount of glycogen present in the body of an infant, this can be rapidly depleted and essentially fasting quotients found after 24 hours. This is especially the case if the infant attempts by muscular activity to increase the body-temperature. While on the first day, at least, the muscular activity would not probably be sufficient to compensate for the low temperature, it would tend to deplete the moderate store of glycogen, thus producing a condition approaching complete inanition, with the possibility of developing an acidosis. It would appear, therefore, that nature has made no unusual provision for supplying a quickly available fuel asset in the form of body glycogen.

Furthermore, the normal supply of food-material from the breast of the civilized, parturient woman during the first few days of the infant's life is admittedly much less than is actually needed for maintenance. The colostrum and the milk during the first week or ten days following the birth of the child have been analyzed by a number of

[1]See pages 84 and 88.

investigators, these including Pfeiffer,[1] V. and J. Adriance,[2] Camerer and Söldner,[3] Czerny and Keller,[4] and Langstein, Rott and Edelstein.[5] Bailey and Murlin[6] also report the results of analyses made by Gephart. The values reported by Czerny and Keller are given in table 22 and those of Gephart in table 23. The energy values per liter of human milk as reported by Langstein, Rott, and Edelstein for the first 7 days after birth are as follows:

First day	1.500 calories per c.c.
Second day	1.100
Third day	.800
Fourth day	.750
Fifth day	.700
Sixth day	.675
Seventh day	.650

TABLE 22.—*Variations in percentage composition of woman's milk (Czerny and Keller).*

	Fat.		Sugar.		Protein.[1]		Ash.		Solids.	
	p. ct.		*p. ct.*		*p. ct.*		*p. ct.*		*p. ct.*	
Pfeiffer	0.758 to 9.053		4.224 to 7.65		1.049 to 3.04		0.104 to 0.446		8.23 to 15.559	
Johannessen and Wang	2.7	4.6	5.9	7.8	.9	1.3	.....		.....	
V. and J. Adriance	1.31	7.61	5.35	7.95	.23	2.60	.09	.28	9.19	15.31
Guiraud	1.75	6.18	6.7	7.7	.85	1.4	.10	.27	11.2	16.3
Camerer and Söldner	1.27	5.77	5.35	7.52	.824	1.87	.11	.36	9.41	14.11
Schlossmann	1.65	9.46	5.2	10.90	.56	3.4	.....		.....	

[1]Nitrogen times 6.25.

TABLE 23.—*Results of analysis of colostrum (Gephart).*

Day.	Protein.	Fat.	Carbohydrate.	Heat values per c.c.	
				Bomb calorimeter.	Physiological heat value.
	p. ct.	*p. ct.*	*p. ct.*	*cal.*	*cal.*
Second	2.56	2.60	7.75	0.667	0.626
	2.63	3.47	5.37	.685	.643
Third	1.79	1.25	8.68	.561	.532
	2.06	5.45	7.04	.903	.870
	2.63	2.06	7.44	.636	.594
Average	2.3	2.9	7.1	.677	.653

The amount of human milk secreted by healthy mothers depends upon the demands of the infants, thus varying with the weight and strength of the child. That it also varies in primiparæ and multiparæ

[1]Pfeiffer, Jahrb. f. Kinderheilk., 1883, **20**, p. 365.
[2]V. and J. Adriance, Archives of Pediatrics, 1897, **14**, p. 22.
[3]Camerer and Söldner, Zeitschr. f. Biol., 1898, **36**, p. 277.
[4]Czerny and Keller, Des Kindes Ernährung, Ernährungsstörungen und Ernährungstherapie, Leipsic and Vienna, 1906, p. 412–417.
[5]Langstein, Rott and Edelstein, Festschrift z. Heubner, Berlin, 1913, p. 405.
[6]Bailey and Murlin, Am. Journ. of Obstetrics, 1915, **71**, p. 526.

is shown by Cramer's[1] values given in table 24. It is obvious that an amount of milk which would be normal for one infant would be abnormal for another, and for this reason average figures as to the amount secreted only give a general idea of what an average infant might take and can not be applied to abnormally strong or weak infants. Von Reuss[2] has collected the estimations made by a number of investigators as to the amount of milk secreted per day by the mothers of infants of different weights; these are given in table 25. The amount of milk taken by the infant during the day was obtained by weighing the mother or the infant before and after nursing. This method is obviously liable to great error, especially when the small amounts of the first few days are to be considered.

TABLE 24.—*Amounts of colostrum and of human milk secreted per 24 hours in primiparæ and multiparæ (Cramer).*

[All values in grams.]

	1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.
9 babies of primiparæ; av. birth wt. 3,290 gm.....	4	78	183	199	236	299	303	274	362	384
7 babies of multiparæ; av. birth wt. 3,348 gm.....	6	129	238	324	344	324	361	365	384	415

TABLE 25.—*Estimation of the daily secretion of colostrum and of human milk (von Reuss).*

[All values in grams.]

Author.	No. of cases.	Birth-weight.	1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.
Kruger, 1875.....	10	.....	12–15	96	192	234	363	441	501	518	621	648
Reusing, 1895....	6	3,060 (2,220–3,650)	38.3	120.8	176.6	220	271.5	296.6	297	333	.....	.....
W. Camerer.....	11	3,126	17	91	193	309	352	391	467	.....	.....	.....
Denecke, 1880...	10	.....	44	135	192	266	352	365	383	411	.....	.....
Baumm and Illner	..	.....	20	75	80	155	218	233	.....	.....	.....	.....
Cramer, 1901....	5	.....	2.5	10.89	89.49	192.6	226	246	311	.....	.....	.....
Feer, 1902.....	7	3,528	4	50	177	315	456	549	552	567	562	603
Aronstamm, 1903.	10	3,403	.....	22.5	79.9	175.5	217.6	242.5	281.8	.....	.....	.....
Beuthhner, 1902..	16	.....	17	91	190	302	348	381	450	476	.....	.....
Klemm, 1907....	3	3,091	.....	13	190	370	460	440	483	.....	.....	.....
Jaschke, 1909....	18	2,700–3,416	19	90	193	260	339	402	415	470	.....	.....
Opitz, 1911.....	75	3,000–3,500	56.7	197.8	296.8	371.5	431	462.8	455.3	485.1	467.6	.....
von Reuss.....	25	2,800–4,000	.....	54	173	263	327	354	362	390	.....	.....

From the data in the foregoing tables it is seen that even under the most favorable conditions the total amount of available energy in the colostrum which the child receives from the mother's breast during the first few days is wholly insufficient to supply the energy needs, even when we consider only the basal metabolism. Still less does this scant

[1]Cramer, Klin. Beitrag z. Frage der künstlichen Ernährung des Neugeborenen. Inaug. Diss., Breslau, 1896. Cited by Czerny and Keller, Des Kindes Ernährung, Ernährungsstörungen und Ernährungstherapie. Leipsic and Vienna, 1906, **1**, p. 356.

[2]von Reuss, Die Krankheiten des Neugeborenen. Berlin, 1914, p. 90.

fuel-supply serve for the probable increment above basal metabolism caused by the restlessness, crying, and varied muscular activity of the infant throughout the day. It is thus seen that the struggle for existence and the struggle for food begin simultaneously with the new-born infant. Since the food-supply is so obviously insufficient, we may ask why nature does not provide more liberally during the first few days. It is a most striking fact that only human mothers and new-born infants are so entirely dependent upon the care of others. The relationship between this fact and the development of civilization is most interesting and leads one to ask if this scant food-supply is a natural consequence of civilization.

We may, furthermore, consider whether, in the absence of a sufficient natural food-supply to compensate for the energy outgo, it is desirable to supplement the normal supply of colostrum with other food-material until the milk is available in the mother's breast. Provision of material for growth may, without danger to the child's welfare, be delayed for one week until plenty of milk is supplied by the mother. Since this would practically be partial inanition, we may reason from the analogy of the prolonged fasting experiment recently reported[1] that the infant may draw upon its own body-reserve for a considerable period of time.

On the other hand, a delay in the maintenance supply of food sufficient to force the infant to subsist upon its own body-reserves may not be without actual detriment. Usually a healthy, well-nourished infant has at birth considerable fat, and, as shown by our study of the respiratory quotient, a moderate supply of glycogen. It is a well-known fact, however, that even with adults during fasting, particularly when there is a deficiency of carbohydrate available for combustion, an acidosis rapidly develops. This is strikingly shown with fasting adults and with adults fed on a carbohydrate-free diet,[2] and has, indeed, been frequently observed with young children.[3] Is this acidosis dangerous, and if so, how can it be combated? From our experience with adults, apparently the best method of combating acidosis is to feed carbohydrate material. If, therefore, supplemental feeding is necessary, it would seem on general principles that the food-material most easily digested and most readily absorbed for oxidation would be a soluble carbohydrate. The carbohydrate possessing these qualities in the greatest degree is dextrose, as it requires no hydrating ferment to convert it into the blood sugar.

If the infant is to be fed, we may again emphasize the fact that a knowledge of the energy requirement for the first week is most important. Those in charge of the child at this time should therefore have

[1]Benedict, Carnegie Inst. Wash. Pub. No. 203, 1915.
[2]Benedict and Joslin, Carnegie Inst. Wash. Pub. No. 176, 1912, p. 125.
[3]Schlossmann and Murschhauser, Biochem. Zeitschr., 1913, **56**, p. 355; see also, Murschhauser, Boston Med. and Surg. Journ., 1914, **171**, p. 185.

practical experience in supplemental feeding, for a disturbance of the digestion in the first few days after birth is most harmful and may even prove fatal. In discussing this point, Morse and Talbot[1] say: "It is very important, when beginning to feed a new-born baby, not to give it too much food or too strong a food. There is no time in a baby's life in which it is so easy to disturb the digestion or at which it is so difficult to correct the disturbance, if it is once caused."

PROBABLE 24-HOUR ENERGY REQUIREMENT OF A NEW-BORN INFANT FOR MAINTENANCE.

From a practical standpoint, therefore, we should know not merely the basal metabolism of the infant during the first week of life, but the probable average metabolism. This would include the superimposed metabolism due to varied muscular activity during the day, the infant when studied in the respiration chamber being quiet and with but little, if any, muscular activity. In discussing the results of our research we have laid special emphasis upon the maximum activity, which we have found to vary from the minimum by 4 to 211 per cent, with an average variation of 65 per cent.[2] To form a conception of the true increase above the basal metabolism, an estimate of the general activity of the infant throughout the day is essential. An estimate of the period of time in which the child has been asleep, awake, or crying may be obtained from the report of the nurse, if the infant is in the hospital, or from some responsible member of the family, if in the home. It is even possible that some simple form of recording crib, with graphic attachment,[3] may be used to indicate the degree of muscular activity as a help in forming an estimate of the amount of food necessary for the total 24-hour energy requirement.

Without taking into consideration the question of growth (and in the first week of the child's life, this may be neglected) we may assume that for infants from $1\frac{1}{2}$ to 6 days old the basal energy requirement is 44 calories per kilogram of body-weight or 12.65 calories per square meter of body-surface per unit of length. Some 10 per cent for the portion rejected as fecal material should be added to this amount, thus making the minimum food requirement approximately 48 calories per kilogram of body-weight. The indefinite but rarely minimum amount of activity of the infant throughout the day would further increase the energy requirement. This may be estimated as about one-half of the average maximum metabolism found in our observations, or 30 per cent, which would give an increase of 14 calories. The daily energy requirement, including both the maintenance metabolism and the metabolism due to activity, would therefore be approximately 62 calories per kilogram per 24 hours—this estimate making absolutely no provision for growth.

---

[1]Morse and Talbot, The nutrition and feeding of infants. New York, 1915, p. 125.
[2]See table 17, p. 112.
[3]Benedict and Talbot, Carnegie Inst. Wash. Pub. No. 201, 1915, p. 60.

MBL/WHOI LIBRARY
WH 18GF 3

9408